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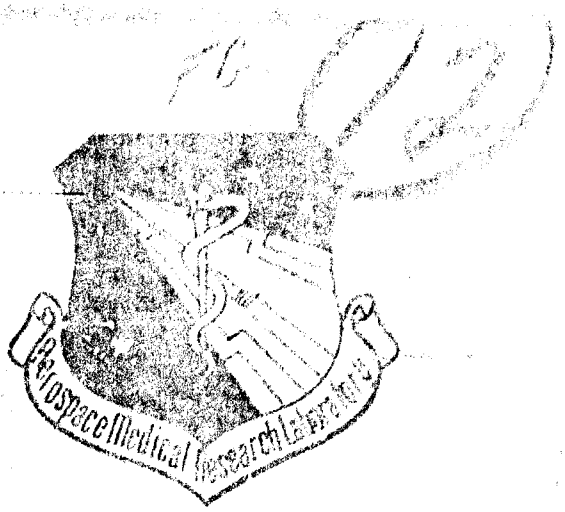

USAF BIOENVIRONMENTAL NOISE DATA HANDBOOK

VOLUME I
ORGANIZATION, CONTENT AND APPLICATION

JULY 1975

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AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE, OHIO 45433

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AMRL-TR-75-50, Volume I

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES C. VON GIERKE
Director
Biodynamics and Biomics Division
Aerospace Medical Research Laboratory

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USAF aircraft, auxiliary equipment, ground power units and other aerospace systems oftentimes produce acoustic environments which are potentially hazardous, interfere with voice communication and task performance, or are annoying. Such environments can adversely affect flight crews, aircraft passengers, ground crews, other flight line personnel, and airbase communities. The Aerospace Medical Research Laboratory has prepared a multi-volume handbook (125+ volumes) which provides data describing typical acoustic environments produced by specific, major USAF systems in standard forms directly useful to bioenviron-

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mental and civil engineers, flight and ground safety personnel and others concerned with human exposure to noise. This handbook provides measured or extrapolated data defining flight crew, ground crew, and far-field noise environments in a wide variety of physical and psychoacoustic measures. It does not, however, include data on noise produced on the ground by aircraft during flight (e.g., takeoff, flyover, approach). This particular volume (Vol. 1) describes the general organization, scope, content and application of the entire multi-volume handbook and covers equipment and procedures for data acquisition and analysis, physical acoustic and psychoacoustic measures of noise, AFR 161-35 noise exposure limits, ear protectors commonly used by USAF personnel, normalization and extrapolation of far-field noise data, and format and examples of handbook data. This volume also describes the handbook index, the distribution of the handbook, and contacts for additional information. The information in this introductory volume is not generally repeated in the other handbook volumes which report data on specific systems.

PREFACE

This handbook was prepared by the Biodynamic Environment Branch (AMRL/BBE), Aerospace Medical Research Laboratory, under Air Force Systems Command Project/Task 72-3104, Measurement of Noise and Vibration Environments of Air Force Operations.

Mr. John Cole prepared this particular volume, which describes the general organization, content, application and other features of the entire handbook.

The several authors of this multi-volume handbook gratefully acknowledge the personal interest and efforts of those many persons who significantly contributed to this undertaking: Mr. Henry Mohlman who prepared the computer software and helped develop the data bank system needed to process data; Lt Col Carl Weinberg, Col George Mohr and Lt Col Hugh Mulligan who strongly supported this program and resource needs; Dr. Horace Parrack, Mr. Henry Sommer, and Dr. Charles Nixon who provided guidelines and data on bioacoustic limits and ear protectors; Mr. Harald Hille and Mr. Keith Kettler who developed instrumentation used in these studies; Mrs. Joan Robinette who edited all reports and arranged for their publication; and Col Owen Kittilstad and Lt Col William Muenker who provided overall direction on handbook distribution requirements.

The author of this report also appreciates the efforts of Mr. Robert Powell who provided many helpful suggestions on content and technical accuracy, Capt Nick Farinacci who helped in technical editing, and Mrs. Norma Peachey who typed this report for her extensive preliminary efforts in putting this volume of the Handbook together.

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INTRODUCTION TO HANDBOOK

PURPOSE

USAF aircraft, auxiliary equipment, ground power units, and other aerospace systems oftentimes produce acoustic environments that are potentially hazardous, interfere with voice communication and task performance, or are annoying. Such environments can adversely affect flight crews, aircraft passengers, ground crews, other flight line personnel, and airbase communities. Personnel protection, voice communication equipment, limiting exposure times, community response, and siting and construction of facilities are some of the factors that must be evaluated.

The Aerospace Medical Research Laboratory (AMRL) prepared this handbook to provide data describing the typical noise environments produced by specific, major USAF systems in standard forms directly useful to bioenvironmental and civil engineers, flight and ground safety personnel, and others concerned with environmental noise. This volume describes the general organization, content, application and other features of the entire multi-volume handbook. It also gives examples of handbook data extracted from other volumes on the KC-135A aircraft,[1] the F-15A aircraft,[2] and MA-3 air conditioner.[3]

The handbook is a tool to assist in environmental assessments. It provides a convenient, consolidated package of bioenvironmental noise data acquired and processed in a uniform fashion, using established engineering practices. It does not provide all the answers nor substitute for the knowledge and skills of trained, experienced personnel.

Our approach toward preparing the handbook was to measure the environments under typical field conditions and use the results to derive those standard physical acoustic and psychoacoustic measures most commonly used to assess noise exposure. Methods and equipment used comply with widely accepted engineering practices. We standardized formats for data presentations used throughout the many volumes of the handbook. In several instances, we used field noise data measured by non-AMRL investigators to derive handbook results. Those sources are acknowledged in the appropriate individual volumes.

Availability of these data should eliminate redundant measurements of the same sources by personnel at different bases who have the same problems and also minimize the requirement for base personnel routinely to measure new systems. Base personnel must continue local measurements, however, to evaluate unique sources, effects of large sound-reflecting surfaces near the region of interest, noise reduction of specific buildings, barriers or obstacles that shield receivers, and other unusual situations.

SCOPE

The handbook focuses on several specific areas and types of noise sources of primary importance because they involve the most serious, wide-spread, bioenvironmental Air Force noise problems.

Three major problem areas are addressed:

In-Flight Noise — Noise environments at flight crew and passenger locations onboard aircraft during typical operations, such as engine start, taxi, takeoff, climb, cruise, gun firing, approach, and landing.

Near-Field Noise — Noise environments produced outdoors close to the source at ground crew locations during ground operations of aircraft, aerospace ground equipment, and other ground-based equipment and facilities. Such locations are in the acoustic near-field of the source where the source appears to be spatially distributed and cannot be regarded as a point source.

Far-Field Noise — Noise environments produced outdoors at moderate-to-large distances from the source, typically at locations on the flight line and in the surrounding community, during **ground operations** of aircraft, aerospace ground equipment, and other ground-based equipment and facilities. Such locations are in the acoustic far-field where the source may be regarded as a point source.

Primary noise sources documented:

Aircraft — More than 60 different military aircraft, including attack, bomber, fighter, reconnaissance/observation, cargo/transport, training, and other types. All are Air Force except for several Navy/Marine Corps aircraft on which we measured only the far-field noise.

Aerospace Ground Equipment (AGE) — More than 40 different AGE units including air conditioners, compressors, generators, heaters, test stands, bomb lifts, and other flightline/aircraft-service equipment used by the Air Force

The handbook does not include data defining the noise produced on the ground by aircraft during takeoff, flyover, approach and landing. Such single-event noise data are available[4] and are used as the data base for NOISEMAP, a computer program and procedure [5, 6, 7, 8, 9] used by the Air Force to predict cumulative exposure to aircraft noise in airbase communities. Reference 4 also includes some far-field noise produced by aircraft ground operations in a different format, but technically consistent with handbook data.

The handbook does not include data on noise environments produced by shop/industrial equipment (e.g., mechanical or hydraulic machine tools), office equipment (e.g., typewriters, duplicating machines), computer facilities (e.g., card readers, line printers), building air conditioning/ventilating equipment (e.g., blowers, compressors), special purpose facilities (e.g., missile control centers, wind tunnels), ground transportation (e.g., trucks, autos), construction equipment (e.g., bulldozers, scrapers), or material handling equipment (e.g., fork lifts, cranes).

Neither does the scope of the handbook include blast noise (e.g., explosives, artillery fire), sonic booms, nor does it provide architectural acoustics data (e.g., transmission loss of structures, absorption of materials).

Data available on older aircraft either out of inventory or being phased out are generally not included but can be obtained from AMRL. See section, Contacts for Information. Such information is sometimes relevant to current hearing compensation claims filed by personnel exposed years ago.

Although the handbook includes data on systems with multiple noise sources (e.g., aerodynamic flow, avionics equipment, propulsion system), it does not attempt to identify specific components producing the noise, analyze the noise generating mechanisms, nor provide guidance on noise control procedures and material.

The handbook will initially contain about 125 volumes and will grow to about 200 volumes as new systems and other significant sources are evaluated.

ORGANIZATION AND CONTENT

The handbook is a multi-volume document published under one report number and general title. Individual, numbered volumes have separate sub-titles (e.g., AMRL-TR-73-50, Volume 3: A-1 Generator Set).

Volumes 1 and 2 present general information not unique to any specific systems. Volume 2[10] provides a method and data for adjusting the handbook's far-field noise data, which are for standard meteorological conditions (15 C temperature, 0.76 meter Hg barometric pressure, 70% relative humidity) to derive comparable data for other conditions. Information in these two introductory volumes is not generally repeated in the other volumes.

Most volumes contain data on specific systems, typically one system per volume. Volume numbers were assigned sequentially as data were ready for publication. Order of the systems in the sequence of volumes is not significant. These individual data volumes organize results into major sections according to the three problem areas previously described: *In-flight noise*, *near-field noise*, and *far-field noise*. For a particular aircraft, we usually combined near-field and far-field data into a single volume and put the in-flight data under separate cover. We grouped all data on any one AGE unit into a single volume.

Each data volume describes the system measured, test conditions and measurement locations. Measured data presented define the physical acoustic levels produced by the source in terms of one-third octave band, octave band, and overall sound pressure levels. Acoustic power levels and directivity indices, derived from the far-field measured data, describe the basic source emission. Several psychoacoustic measures, calculated from the physical measurements, provide data required to assess the impact of this noise on people. Such measures include: C-weighted and A-weighted overall sound levels, preferred speech interference level, tone-corrected perceived noise level, and limiting values for total daily exposure of personnel with and without standard Air Force headgear/ear protectors as specified in AFR 161-35[11]. The A-weighted overall sound levels reported in the handbook can also be used to determine compliance with Department of Labor rules set forth in its Occupational Safety and Health Standards.

We also normalized the far-field data to standard reference distances and meteorological conditions, which facilitates data comparison between different systems. We then extrapolated these normalized data and derived contours defining the different measures as functions of distance and angle from the source.

Detailed definitions and samples follow later in this report.

INDEX

Ideally, the handbook would present the results in a well-ordered sequence of volumes organized in accordance with classes of systems and types of data along with a complete index published as an integral part of the document. This would be feasible if all data were on-hand at the start of the publication effort and no new systems nor additional data were going to be added. But, such is not the case.

Consequently AMRL has prepared a 3-part index, which we will periodically update as volumes are added and will distribute separately from the handbook:

Part A — identifies each published volume, listed numerically, giving volume subtitle, author(s), Defense Documentation Center (DDC) accession document number, and publication date.

Part B — lists alpha-numerically those aerospace systems contained in the handbook, identifying the specific volumes containing each type of environmental noise data available (i.e., in-flight, near-field, far-field).

Part C — is the same as Part B except that it lists the aerospace systems alpha-numerically within system classes (e.g., military aircraft-fighter, aerospace ground equipment — generator).

DISTRIBUTION

Each handbook volume contains information on the front cover regarding limits, if any, on distribution. Most have been approved for public release with unlimited distribution. A few volumes may have restrictions that must be observed.

AMRL is directly distributing printed copies of the handbook on a one-time basis to about 200 Air Force organizations responsible for bioenvironmental noise problems, including most base and regional hospitals, clinics, command surgeon, and civil engineering offices. Appendix A lists, alphabetically by airbase or location, all addressees on the initial distribution. It also specifies the number of copies sent to each addressee.

We will not distribute copies to organizations within the Air Force or other government agencies not having a major, continuing, direct Air Force-mission-related need; nor will we distribute copies to any nonfederal-government organization. If you believe your organization qualifies to be on distribution, direct a written request to Headquarters, Aerospace Medical Division. See section, Contacts for Information.

Any organization or individual can obtain copies of all unlimited volumes from NTIS or DDC as noted inside the front covers.

AMRL will routinely send the handbook index, typically 6 to 8 pages long, to all addressees on distribution for the handbook itself. Any other organization interested in receiving this index should write AMRL. See section, Contacts for Information. At this time you cannot obtain this index from NTIS or DDC; we may ultimately publish the index and make it available from these sources when the potential for additions/changes is less.

FUTURE PLANS

AMRL intends to expand or modify this handbook as required, adding information on other systems, revising data based on changed technical standards, and making other changes based on the experience and needs of the handbook user.

We will measure new aircraft and major AGE items as they come into inventory. Our objective is to acquire data as early as possible, preferably during system development. Aircraft ground runup noise suppressors and jet exhaust deflectors used behind runup pads are two noise source factors we are also considering.

The handbook contains many results that have been calculated or extrapolated from measured data, using standard, generally accepted methods. Realistically, one must recognize that some of these standards are not precise and will be changed when better information is available (e.g., on the effects of the atmosphere, ground cover, and obstacles on sound propagation). Some of these future changes may require AMRL to modify parts of the handbook.

CONTACTS FOR INFORMATION

Direct any questions concerning the technical data in this handbook, requests for additional data, and requests for the handbook index to the Aerospace Medical Research Laboratory, Biodynamic Environment Branch. Mail address and telephone:

AMRL/BBE
Wright-Patterson AFB, OH 45433

AUTOVON 785-3675 or 785-3664
Commercial (513) 255-3675 or (513) 255-3664

Direct all requests to be placed on handbook distribution to Headquarters, Aerospace Medical Division.

Mail address: Hq AMD/RDF
Brooks AFB TX 78235

AMD and AMRL will continue to consider requests by Air Force organizations for special bioenvironmental noise data we can readily generate for special problems or meteorological conditions, using the noise data bank and OMEGA software discussed in the next section. Direct such requests to AMRL/BBE.

DATA ACQUISITION AND ANALYSIS

INSTRUMENTATION

The handbook presents measured noise data recorded in the field on magnetic tape and analyzed in the laboratory. Equipment and methods used follow widely accepted engineering practices. Thorough and regular acoustical and electronic calibration of all measurement systems provided information on system frequency response, dynamic range, linearity, distortion, and operating limits. Such calibration enabled accurate corrections (± 1 dB) to compensate for instrumentation characteristics and assure that operations were properly within equipment limits; i.e., not overdriven nor operated too close to the electronic noise floor inherent in the measurement system.

Microphones

All AMRL measurement systems with one exception use Bruel and Kjaer condenser microphones to transduce acoustic pressure at the point of interest into an analogous electrical signal for recording and analysis. This type microphone comes in several sizes each with different sensitivity and frequency response. We select the microphone best suited for each measurement.

The exception noted above is a miniature electret-condenser microphone we use as part of MICROPAK, a small instrument package worn by the pilot and applied primarily to acquire in-flight noise data on single-seat fighter aircraft. This small microphone mounts on a very lightweight boom attached to the flight helmet.

A foam or other type windscreen placed over a microphone minimizes spurious signals produced by wind or other airflow over the microphone. AMRL measurement procedures require windscreens for all outdoor tests and certain other measurement situations; e.g., in-flight measurements on board aircraft with doors or hatches open.

AMRL regularly calibrates its microphones with and without windscreens, using standard comparison and/or reciprocity techniques. These procedures include absolute calibration and comparison against standard microphones periodically calibrated at the National Bureau of Standards. Results include microphone frequency response as a function of angle of sound incidence on the microphone diaphram; e.g., perpendicular, grazing and random incidence.

Recorders
Use of magnetic tape recorders enables data to be quickly acquired in the field and preserved for detailed analyses. Selection of specific recorders for individual tests depended primarily on the frequency range needed, number of data channels required, and size and weight limits. For most measurements we used modified NAGRA IV one- and two-channel direct recorders. AMRL modifications on these small, precision, battery-operated units provide special signal conditioning, extended low frequency capability using a voltage-controlled-oscillator circuit, incremental logarithmic gain control, voice annotation, and other control features.

MICROPAK, the small in-flight measurement system worn by the pilot, incorporates a miniature NAGRA SN recorder. Special signal conditioners, tape recorder control logic and pilot voice annotation features are built into a lightweight unit strapped like a clipboard onto the pilot's upper leg. The recorder slips into a pocket in the flight suit.

Spectral Analyzer
AMRL analyzed all recorded data with a General Radio 1921 Real-Time Spectral Analyzer system directly interfaced with a Control Data CDC-1700 computer, high-speed card punch and line printer. This high-volume system quickly determines in one pass the spectral content of an input signal with 1/3 octave band resolution over a range of preferred frequency bands centered from 3.15 to 50,000 Hz. The system provides a selection of nine different true integration periods for the root-mean-square detector: 1/8, 1/4, 1/2, 1, 2, 4, 8, 16 and 32 seconds.

Computer Facility
We further processed these spectral data, using a CDC 6600 computer system at the Aeronautical Systems Division's Computer Center, Wright-Patterson AFB. Input/output was made via batch terminal, which includes a CDC 1700 computer, card reader, card punch, line printer, plotter and other peripherals. This processing provided essentially all the data tables and figures presented in the handbook.

FIELD MEASUREMENTS

In-flight Noise
Aircraft propulsion systems, aerodynamic flow over the aircraft skin, and on-board equipment all produce noise that can contribute to the total complex sound field present at any on-board location. Aircraft structural characteristics, sound reflective surfaces, degree of aircraft insulation and other factors also influence the resultant environment. At some locations the sound might be coming predominantly from one source or one direction, e.g., from a piece of noisy on-board gear. Generally, these sound fields are more diffuse with sound impinging from many directions.

AMRL measured the noise environments at aircraft flight crew and passenger locations during typical operations. The number of locations varied widely from a single location in a fighter (e.g., pilot position in F-4D) to more than 60 locations in large cargo or transport aircraft (e.g., crew positions and troop locations in C-5A). Test conditions typically included engine start, taxi, runup, takeoff, climb, cruise, approach and landing. Occasionally we also measured noise produced by weapon fire and combat maneuvers, such as a dive. Table 1 is an example of how the handbook reports these locations and conditions. A number designates each specific location. A letter designates each test condition. Many of the handbook tables use this numeric/alphabetic designator to identify the location/condition pertinent to the data presented. Examples come later.

TABLE 1

MEASUREMENT LOCATIONS AND TEST CONDITIONS

KC-135A, Wright-Patterson AFB, 17 Sep 1974
Serial # 57-1428

LOCATION	*POSITION*	*HEIGHT ABOVE DECK*
1	C/L Pilot and Copilot	Seated Head Level
2	Navigator's Station	Seated Head Level
3	Cellestial Navigator's Station	Seated Head Level
4	Boom Operator's Forward Station	Seated Head Level
5	Forward Latrine	1.5 Meters
6	Forward Latrine	Seated Head Level
7	FS 420 (Galley), Right of C/L	1.5 Meters
8	FS 740, Right Side	Seated Head Level
9	FS 900, Right Side	Seated Head Level
10	FS 960, Right Side	Seated Head Level
11	FS 1080, Right Side	Seated Head Level
12	FS 1200, Right Side	Seated Head Level
13	Aft Latrine	1.5 Meters
14	Boom Operator's Aft Station	Reclining Head Level
15	APU Operator's Panel (FS 1180)	1.5 Meters

CONDITION	*DESCRIPTION*
A	APU operating — 100% rpm (38,000 rpm)
B	All 4 engines idle — 60% rpm, forward crew hatch open, windows closed
C	All 4 engines idle — 60% rpm, forward crew hatch closed, windows closed
D	Taxi — 65% rpm, copilot's window open
E	Takeoff — wet, climbing to 1000′ PA, 2.83 EPR, 95% rpm
F	Climb — Normal Rated Thrust (NRT), dry, 1000′→15,000′ PA, 2.1 EPR, 85% rpm
G	Climb — Military power, 13,000′ PA, 2.7 EPR, 90% rpm
H	Military power — 18,000′ PA, 2.7 EPR, 90% rpm
I	Maximum Range Cruise — 28,000′ PA, 2.9 EPR, 85% rpm
J	Orbit Cruise — 28,000′ PA
K	Refueling Operation — 28,500′ PA
L	Climb — Military Power, 28,500′→35,000′ PA
M	Maximum Range Cruise — 35,000′ PA, 240 KIAS, 2.0 EPR
N	Maximum Range Cruise — 37,000′ PA, 440 KIAS, 3.0 EPR
P	Penetration Descent — 35,000′→20,000′ PA, 350 KIAS
Q	Intermediate Level — Off — all engines idle, 20,000′ PA, 300 KIAS, 1.7 EPR
R	Penetration Descent — all engines idle, 20,000′→5000′ PA, 1.2 EPR
S	Penetration Descent — all engines idle, 5000′→2000′ PA, 220 KIAS, flaps and gear down
T	Approach Phase — 2,000′ PA, gear down, flaps 40°
U	Missed Approach Go-around-Takeoff power, dry

On single-seat fighter aircraft we mounted the microphone in one or more fixed positions, generally attached to the pilot's helmet on a thin boom at ear level, 0.1 to 0.3 meter from the side of the helmet, and pointed in a forward direction. Generally we considered the sound field to be randomly incident on the microphone and applied microphone calibrations accordingly. Sample times typically ranged from 15-30 seconds.

On other aircraft, AMRL, with the assistance of flight personnel, selected crew and passenger locations of interest. At each location we then defined a volume, typically 0.5 meter in diameter, in which the person's head would normally move while occupying that location. While recording data at each location, the test engineer held the microphone at arm's length and smoothly, but randomly moved it throughout the defined volume. If the sound field were clearly directional, he pointed the microphone directly at the source. Otherwise, he randomly changed the microphone's orientation angle throughout the sample to further randomize the sound wave's incidence on the microphone. Pertinent microphone calibrations were accordingly applied during analysis. Typical sample times varied from 8-30 seconds. This scanning method compared to a fixed microphone provided data samples more representative of levels to which personnel are exposed.

We conducted these types of measurements at both occupied and unoccupied locations. Flight crew were usually in position. Although the presence of a person, including the noise test engineer, somewhat modified the sound field, we did not consider such effects significant especially when compared with possible effects of other variables; e.g., aircraft power setting, airspeed, movement of persons in the sound field, internal equipment configuration. The noise test engineer also made special effort to position himself so as to minimize the influence of his presence.

Each location/condition was usually measured once. Sometimes we repeated measurements to determine average, maximum and minimum levels.

Near-field Noise

During pre-flight, maintenance, or engine trim operations, the aircraft engines, any onboard auxiliary power unit (APU), and a variety of aerospace ground equipment (AGE) can all generate considerable acoustic energy. Each can significantly contribute to ground-crew exposure, depending on relative source strengths, crew location, and the influence of sound-reflecting or shielding surfaces, such as a fuselage, wing or ground. Like the in-flight situation, these ground-crew sound fields can tend toward being either directional or diffuse. Usually the sources are distributed such that significant sound energy impinges the measurement locations from several directions. Such environments are classified as near-field noise environments.

AMRL measured the noise environments at many representative ground-crew locations during typical flight line operations. Specific locations and test conditions were selected in consultation with experienced maintenance and operations personnel. Noise levels were sometimes measured on aircraft operating alone and other times for aircraft operating concurrently with supporting AGE. We also routinely measured most AGE units separately away from any aircraft and using load banks if appropriate.

The number of locations measured depended on source size and type operation and typically ranged from 3-8 locations on fighters/trainers, from six to twelve locations on bombers/transports and 36-40 locations on AGE. Figures 1 and 2 are examples from the handbook

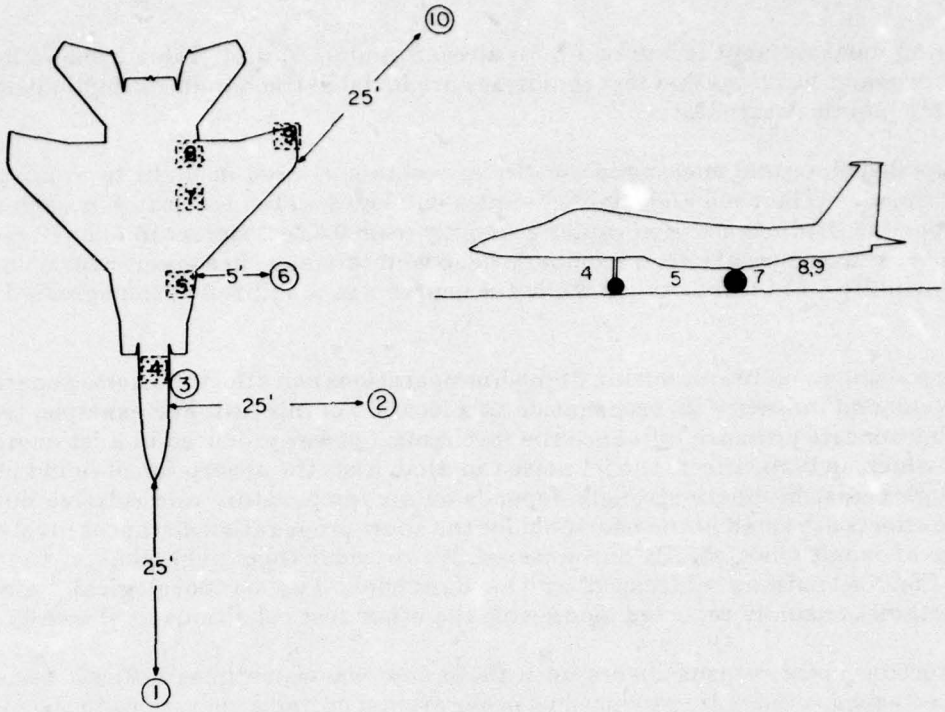

Figure 1. Measurement Locations, F-15A Aircraft, Near-Field Noise[2]

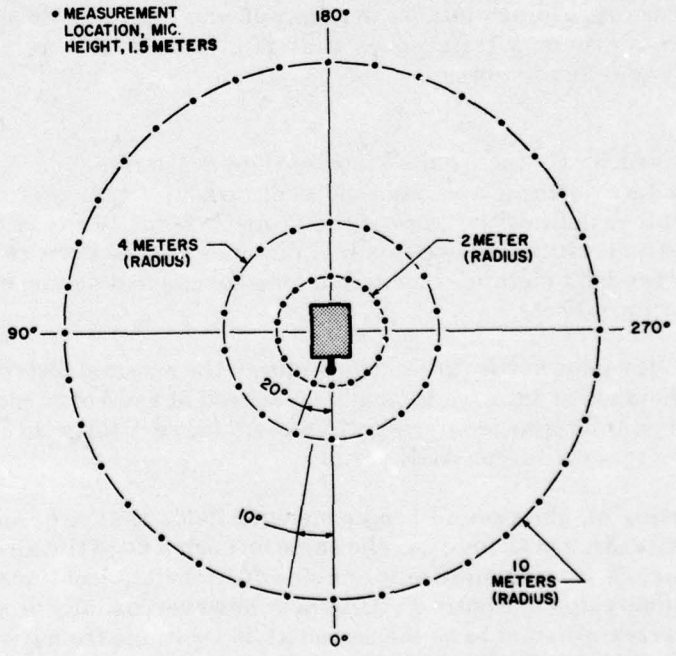

Figure 2. Measurement Locations, MA-3 Air Conditioner, Near and Far-Field Noise[3]. Near-field Location at 2 Meters and 4 Meters Radii

showing measurement locations for an aircraft and AGE unit. Table 2 shows how aircraft measurement locations and test conditions are listed in the handbook, again using numeric and alphabetic designators.

We applied the same microphone scanning techniques used in flight to acquire near-field data samples. The need and the techniques employed were identical. For each sample the microphone scanned a region ranging roughly from 0.5 to 2 meters in diameter, selected to sample the exposure of a crew member's head while engaged in a specific task. Sample times were usually 5-15 seconds taken while the source was stabilized at the specified test condition.

Meteorological conditions during flight-line operations can affect the noise generated by the source(s) and influence its propagation to a location of interest. For example, temperature and barometric pressure influence the mechanical power produced in a jet engine exhaust flow, which, in turn, affects the jet noise radiated. Also, the absorption of sound propagating through the atmosphere strongly depends on air temperature and relative humidity. All these effects are small in the near-field for the short propagation distances involved and the range of conditions typically encountered. We consider them negligible for the flight-line-near-field situations addressed by the handbook. The meteorological conditions are nevertheless usually reported along with the other test conditions as shown in Table 2.

Conducting noise measurements on a flight line was sometimes difficult because of unwanted background noise produced by other ground or flight operations in the vicinity. The test objective was to acquire data on a particular situation of interest and to exclude any spurious data on unrelated sources. We scheduled and located tests so that such influences were minimal. In addition, we regularly recorded samples of the background noise present immediately before starting up or after shutting down the source of interest. These background noise recordings enable deletion of any spurious data during analysis. Test personnel were alert for interferences that might occur during any test and took new samples if they had any doubts.

Far-field Noise

If you go out sufficiently far from a stationary noise source, you reach a distance beyond which the sound wave-fronts are spherical and the sound appears to have emanated from a point. This distance defines the edge of the acoustic far-field that extends outwards therefrom. Noise data measured at one far-field distance can be extrapolated to obtain similar data for other far-field distances by accounting for geometric dispersion, atmospheric absorption, and other effects.

The distance to the edge of the far field depends on the size and distribution of the source. In acquiring far-field noise data, we typically measured at radii of 35 meters for small aircraft, 75 meters for medium-to-large aircraft, 125 meters for very large aircraft, 5 meters for small AGE, and 10 meters for larger AGE.

Aircraft operating on the ground produce sound fields that are laterally symmetric with respect to the aircraft centerline; i.e., the same on each side of the aircraft at the same angle and distance. Hence, we measured only one side of aircraft at locations spaced at 10° intervals from 0-180° as illustrated in Figure 3. AGE units, however, usually produced sound fields that were not symmetric and had to be measured at 36 locations from 0 — 360°, Figure 2. **For all far-field handbook data, the forward direction of the aircraft or the AGE tow bar direction defined the 0 degree reference azimuth.**

TABLE 2

MEASUREMENT LOCATIONS AND TEST CONDITIONS
FOR NEAR-FIELD NOISE MEASUREMENTS

F-15A Aircraft, Ground Runup, Edwards AFB, CA
28 January 1974
Tail #10282

Ground Crew Location	
1 through 10	Near Field Grid
Aircraft Engine (and AGE) Operation	
A	Jet Fuel Starter (unloaded)
B	Both Engines Idle
C	Both Engines 80% RPM
D	Left Engine Military
E	Left Engine Full Augmentation
Meteorology	
Temperature	12.8 C
Bar Pressure	.703 M Hg
Rel Humidity	26 %
Wind — Speed	1 M/Sec
— Direction	340 Deg

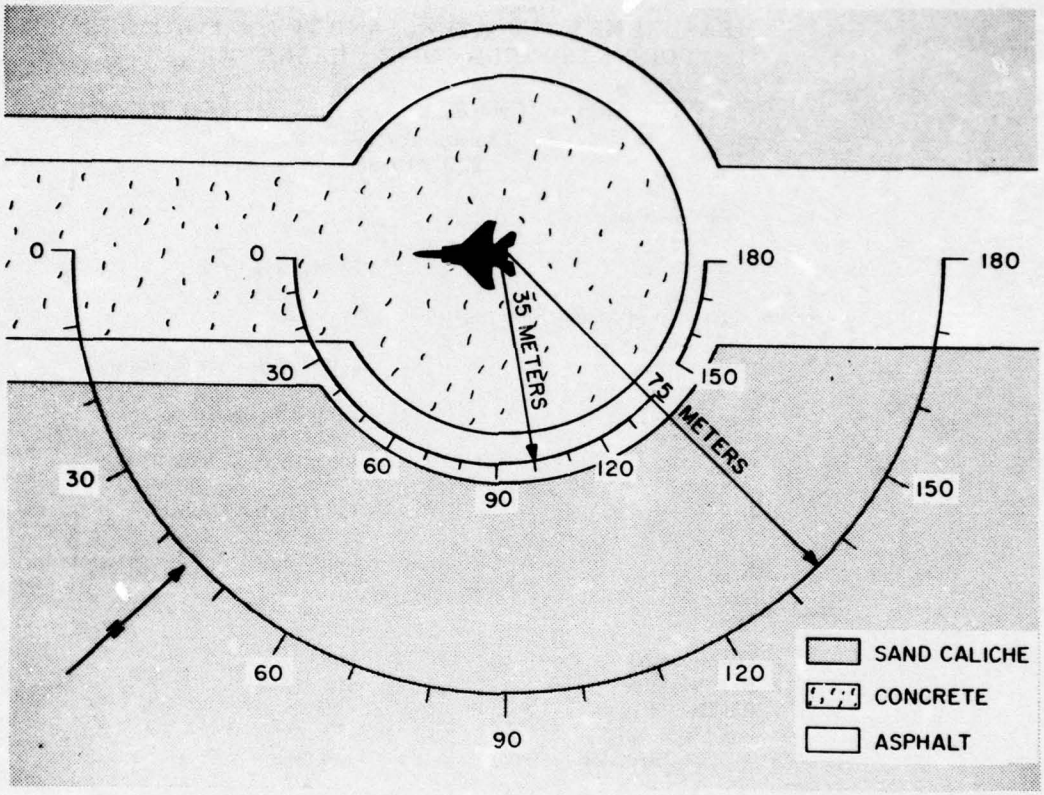

Figure 3. Measurement Locations, F-15A Aircraft, Far-Field Noise[2]

Aircraft operate over a wide range of power conditions during maintenance, engine trim and preflight operations. AMRL measured the far-field noise produced by single and/or multi-engine operations generally at three to five power settings typical for each aircraft including idle through maximum power. Table 3 is an example of how the handbook summarizes these test conditions. In contrast most AGE units normally operate at a single standard power setting and were so measured with load banks if appropriate.

TABLE 3

TEST CONDITIONS
FOR FAR-FIELD NOISE MEASUREMENTS[2]

F-15A Aircraft, Ground Runups, Edwards AFB, CA
28 January 1975
Tail #10282

Aircraft Engine Operation	
Jet Fuel Starter	Engines off
Idle	Both Engines 63 % RPM, Core Speed 395 C, Fan Turbine Inlet Temperature 950 LBS/HR, Fuel Flow
80% Runup	Both Engines 80 % RPM, NC 925 C, FTIT 7,300 LBS/HR, FF
Intermediate (Military)	Both Engines 90 % RPM, NC 925 C, FTIT 7,800 LBS/HR, FF
80% Runup	Left Engine 80 % RPM, NC 690 C, FTIT 4,150 LBS/HR, FF
Intermediate (Military)	#1 (Left) Engine 90 % RPM, NC 930 C, FTIT 7,850 LBS/HR, FF
Full Augmentation	#1 (Left) Engine 90 % RPM, NC 930 C, FTIT 39,200 LBS/HR, FF
Meteorology	
Temperature	12.8 C
Bar Pressure	0.703M Hg
Rel Humidity	26 %
Wind — Speed	1 M/Sec
— Direction	340 Deg.

Test sites were over hard surfaces, generally concrete, and free of any significant sound-reflective surfaces or obstacles except for the ground plane. We positioned load banks, test equipment and personnel so they would not interfere with measurements.

In a few instances we measured aircraft on test pads with exhaust blast deflectors behind the aircraft. Such deflectors can influence the far-field noise, generally decreasing levels aft of the aircraft, but, sometimes moderately increasing levels in other directions. We expect to report more information on blast deflector effects in future handbook volumes.

Aircraft engine exhaust flow at high power settings often prevented noise measurements at the 170-180° locations. At these angles we sometimes moved farther out where flow velocities were less. Usually we did not measure these 170-180° locations for high power settings because aircraft noise typically radiated in this sector is relatively unimportant being 20-25 dB less than that at 160°. There were no similar flow-related problems with AGE and we measured all 36 far-field locations.

Meteorological conditions affect the far-field noise produced by any source causing changes in the source emission and/or attenuation during propagation. As already noted in the near-field discussion, we consider the effects on source emission to be small and negligible for purposes of the handbook. But, the effects on the propagating sound and subsequent far-field noise are not small and cannot be neglected. The handbook always specifies the meteorological conditions at the time of far-field measurements; e.g., Table 3. Many of the far-field data presented in the handbook are corrected to standard temperature, barometric, and humidity conditions. To minimize such corrections, we generally limited the range of conditions acceptable for field measurements to: no precipitation; temperature, 5-30C; relative humidity, 30-90%; winds, less than 3 meter/sec (6 knots). These restrictions comply with or are more stringent than FAR Part 36[12] test conditions specified for aircraft noise certification measurements.

The noise produced at a far-field location consists of direct-radiated sound plus sound reflected by the ground. For some source-receiver heights, separation distances, and ground surface conditions, the reflected sound interacts with the direct sound to produce anomalies in the sound spectra measured at some fixed height. These anomalies occur in the form of spectral peaks or valleys (typically 1 to -3 dB) that occur for one or more frequency bands, usually from 500 to 2500 Hz. If such spectra are used to derive sound levels at other far-field locations, these anomalies carry through into the extrapolated data.

We acquired far-field data on all AGE and a few aircraft using fixed-height microphones (1.5 to 1.8 meters). Handbook data on these systems therefore contain small anomalies that are not generally significant enough to worry about, since they only slightly affect the noise measures used to assess risks to hearing and voice communication capabilities. Nevertheless, far-field data acquired by fixed-height microphones are not ideal baselines for extrapolating to other distances where such anomalies don't necessarily occur in the same degree, or in the same band, or don't occur at all.

During this project AMRL developed a sampling technique to acquire better baseline data for derivation of far-field handbook data. At each measurement location test personnel uniformly moved the microphone along a vertical path from 0.5 meter up to 3 meters above the ground, keeping the microphone pointed at the source. Sample times on this spatial scan ranged from 5 to 10 seconds for each stabilized test condition. During analyses we time-integrated over the complete scan to obtain a power-averaged sound pressure level spectrum. This method minimized the peak-and-valley spectral anomalies caused by ground

reflections and provided better reference spectra for deriving extrapolated data with fewer such anomalies. We applied this microphone-scanning technique for most aircraft far-field measurements reported in the handbook.

Background noise was an even more important consideration for far-field noise studies than for the near-field because source levels were generally lower and the potential for being close to interfering background sources was sometimes greater. Test personnel used the same techniques of scheduling and locating tests to minimize interference, and frequently recording background noise samples for analyses.

SPECTRAL ANALYSIS

We analyzed all recorded data samples using the analog-digital system described earlier. Such analyses determined the spectral content of each sample in terms of one-third octave band sound pressure levels over a range of preferred frequency bands centered from 25 to 10,000 Hz for most handbook data. Table 4 lists the standard preferred frequency [13] bands including nominal band center frequencies and band limits for octave and 1/3 octave bands. A few times we extended this frequency range if significant energy were apparent in other bands.

These spectral band levels were based on the root-mean-square (rms) sound pressure occurring in each frequency band during a particular integration time period. For most handbook data we used true integration times ranging from 1 to 16 seconds depending on the sample stationarity. For in-flight and near-field samples acquired with scanned microphones we typically used 4- or 8-second integration periods to derive power-averaged levels that properly represent the exposures personnel receive as they normally move about at the locations of interest.

Far-field samples recorded with the vertically-scanned microphones contained spectral variations induced by ground-reflected sound as a function of microphone height during the scan. We used 4- or 8-second integration times to derive spectral levels that were power-averaged over the whole scan. These averaged spectra contain minimal ground reflection anomalies and serve as a better baseline for extrapolating far-field spectra.

During these analyses we electronically corrected each spectrum for any non-flat frequency response of the total system used to acquire and analyze that particular data. These corrections were derived from acoustic and electronic calibration signals routinely recorded before each test and analyzed with the exact same equipment used for acquiring and analyzing the environmental data. Corrections included the frequency response of the microphone and windscreen, taking into account the incidence of the sound on the microphone diaphragm; e.g., perpendicular, grazing or random. These corrections were typically ± 1 dB or less for frequency bands below 6,300 Hz, and -3 to 10 dB for the 6,300 to 10,000 Hz bands. Microphone response for grazing sound incidence caused the larger corrections in the high frequency bands.

We analyzed each background noise sample in the same way and over the same frequency range applicable to the test data. Microphone corrections for these analyses depended on judgment as to probable angle of incidence of the controlling background noise on the microphone. In some instances when the background noise was very low, the electronic noise inherent in the measurement system influenced or set the spectral levels in some bands. For simplicity we chose to apply microphone corrections as though all band levels represented the acoustic background and none were electronic noise. By so doing we in effect improperly

TABLE 4

FREQUENCY BANDS[13]

1/3 Octave Band		*Octave Band*	
Center Frequency (Hz)	*Band Limits (Hz)*	*Center Frequency (Hz)*	*Band Limits (Hz)*
12.5	11.2 — 14		
16	14 — 18	16	11.2 — 22.4
20	18 — 22.4		
25	22.4 — 28		
31.5	28 — 35.5	31.5	22.4 — 45
40	35.5 — 45		
50	45 — 56		
63	56 — 71	63	45 — 90
80	71 — 90		
100	90 — 112		
125	112 — 140	125	90 — 180
160	140 — 180		
200	180 — 224		
250	224 — 280	250	180 — 355
315	280 — 355		
400	355 — 450		
500	450 — 560	500	355 — 710
630	560 — 710		
800	710 — 900		
1000	900 — 1120	1000	710 — 1400
1250	1120 — 1400		
1600	1400 — 1800		
2000	1800 — 2240	2000	1400 — 2800
2500	2240 — 2800		
3150	2800 — 3550		
4000	3550 — 4500	4000	2800 — 5600
5000	4500 — 5600		
6300	5600 — 7100		
8000	7100 — 9000	8000	5600 — 11200
10000	9000 — 11200		
12500	11200 — 14000		
16000	14000 — 18000	16000	11200 — 22400
20000	18000 — 22400		

NOTE: 1. Frequencies have been rounded slightly for ordinary use.

2. Higher and lower frequencies can be obtained by successive multiplication or division by 1,000.

changed the background noise spectra in those bands controlled by electronic noise. Usually the electronic noise was very low and did not appear in background spectra. When it did, it appeared only in a few bands. And in those cases the improper change we induced was almost always an increase, because the microphone corrections were usually positive. The net result was a background noise spectra that either accurately represented the background noise or was probably artificially high in a few bands by a few dB. This means that we were almost always very conservative when we removed the influence of such spurious noise (method discussed later in section on sound pressure level) in that we tended to throw away slightly more test data than necessary rather than keep data that should have been thrown out because of the influence of background or electronic noise.

The analysis system produced all spectral output in the form of CRT graphic displays, computer printer tabs and punched data cards used to edit and store the data for further processing.

NOISE DATA BANK

During the last five years AMRL with the University of Dayton Research Institute (UDRI) developed and implemented at this Laboratory a data bank system to readily store, retrieve, and index large volumes of measured and calculated noise data defining Air Force bioacoustic environments.

This data bank contains three general kinds of information stored in a combination of computer punched cards, magnetic tape files, disc files and printed tabs:

Test Descriptions — includes identification of measured systems, test site descriptions, operational test conditions, meteorological test conditions, location/condition designators, and assigned codes for aircraft, operation and processing.

Measured Noise Data — primarily consists of analyzed one-third octave band sound pressure level spectra, sometimes with IRIG B 100 pps time code.

Calculated Noise Data — includes all computer program output used by AMRL to prepare the handbook, conduct in-house research, and accomplish special analyses of specific operational noise problems.

Several continuously updated indexes, generated by computer on demand, enable the user to readily determine availability, extent, form and location of all data in the system. These indexes, which are completely separate from the handbook index, also summarize source descriptions, test conditions, and key parameters used in data processing.

OMEGA PROGRAMS

The measured noise data stored in the bank quantify the physical acoustic environments produced at specified locations by particular test operations. We further processed these baseline spectral data to derive standard physical acoustic and psychoacoustic data that define these environments and help assess their effects on people.

Working together, AMRL and UDRI developed a series of computer programs named OMEGA, which could accomplish such processing in efficient, uniform and accurate ways, custom-tailored to a variety of needs. Up to the present time we have developed nine different OMEGA programs; e.g., OMEGA 1, OMEGA 5, OMEGA 9. Most evolved through several versions; for example OMEGA 1.4 means version 4 of OMEGA 1. We prepared all handbook data thus far using OMEGA 1.4 and OMEGA 3.2. Each handbook data table and figure produced by these programs contains a block in the upper right corner that identifies the specific OMEGA program used.

OMEGA 1.4 operates on **far-field** sound pressure level spectra measured at given angles for one radial distance under one set of meteorological conditions. Within practical limits it derives extrapolated spectral data for the same angles at any far-field distance for any meteorological condition. Using these spectra the program then calculates all the various noise measures described in the next section. The program user can restrict such extrapolations and computations to specific measures at specific locations or can, for example, call for complete graphic contours, defining levels at all angles and distances within selectable limits.

OMEGA 3.2 operates on spectral data measured at any location for any meteorological condition. But, it cannot extrapolate the measured data to other distances nor for other meteorological conditions. This program calculates the various noise measures only for the input spectra and input test conditions. We applied OMEGA 3.2 to all **in-flight and near-field** data.

Detailed descriptions of the OMEGA programs, their operation and application are outside the scope of this report. This volume does, however, define the measures and document the basic equations used for the handbook so that the reader can calculate data for himself in the same way.

MEASURES OF NOISE

The purpose of this section is to define the physical acoustic and psychoacoustic measures presented in the handbook and to identify sources of information that further describe these quantities. All units are metric (mks) and all logarithms used in equations are common (base 10).

SOUND PRESSURE LEVEL

Sound waves propagating through air produce changes in the pressure present at any point in the medium. Such incremental changes from the static pressure are called the instantaneous sound pressure [p(t)]. The effective sound pressure [p] at a point is the root-mean-square (rms) value of the instantaneous sound pressure determined over a specified integration time interval T.

$$p = \left[\frac{1}{T}\int_o^T p^2\,(t)dt\right]^{1/2}$$

A common way of expressing this effective sound pressure is in terms of the sound pressure level (SPL) in decibels (dB).

$$SPL = 20 \log \frac{p}{p_{ref}} \quad \text{dB}$$

where

p_{ref} = reference effective sound pressure = 2×10^{-5} newton/square meter. Substituting p_{ref} into the equation for SPL yields the following:

$$SPL = 20 \log p + 94 \quad \text{dB}$$

The measured data are reported in terms of **overall** and **band** sound pressure levels. The overall sound pressure level (OASPL) defines the effective sound pressure contained in the overall frequency range measured. But, it is not sufficient to know only the OASPL; the

distribution of sound energy as a function of frequency determines the way that the sound propagates and its subsequent effects on people. We accomplished the spectral analyses described earlier to determine the band SPLs that define the effective sound pressure contained in specified frequency bands (Table 4).

For each test we measured and analyzed samples of noise produced by the source to derive 1/3 octave band SPLs, which we will call RSPL's for this discussion. Similarly, for near-field and far-field measurements we derived 1/3 octave band SPLs for the background noise, which we call SPLNs. Both type spectra are stored in the data bank and used as input to OMEGA 1.4 and OMEGA 3.2, which performed the following steps to remove the influence of any background noise:

For each 1/3 octave band f

(1) If $(RSPL_f - SPLN_f) \geq 16$, then the $SPLN_f$ had no significant influence on the $RSPL_f$ which was used with no changes for further processing.

(2) If $6 < (RSPL_f - SPLN_f) < 16$, then the $SPLN_f$ slightly affected the $RSPL_f$ which was corrected as follows before further processing:

$$RSPL_f = 10 \log \left[\text{antilog}\left(\frac{RSPL_f}{10}\right) - \text{antilog}\left(\frac{SPLN_f}{10}\right)\right]$$

Such corrections ranged from 0.1 to 1.2 dB.

(3) If $(RSPL_f - SPLN_f) \leq 6$, then the $SPLN_f$ excessively influenced the $RSPL_f$, which was then deleted from the spectrum and not considered as data.

Generally little or no data were deleted or required correction, because the instrumentation and measurement methods provided large signal/noise ratios throughout the frequency range of interest. The OMEGA programs flagged all corrected band SPLs on all tables of **measured** data.

The OMEGA programs used those band SPLs that were free of spurious background/electronic noise to calculate the OASPL for each measured spectrum by summing the power contained in all those contiguous frequency bands that spanned the overall range measured. This relationship is:

$$OASPL = 10 \log \sum_f \text{antilog}\left(\frac{SPL_f}{10}\right) \quad \text{dB}$$

where

f = frequency band in measured range.

SPL_f = band SPL for frequency band f.

The handbook reports these derived band and overall SPLs as the basic measured data. It also reports octave band SPLs calculated from measured, normalized or extrapolated 1/3 octave band SPLs by summing the power contained in the three 1/3 octaves that make up each octave. This summation is:

$$SPL_f = 10 \log \sum_{f'} \text{antilog}\left(\frac{SPL_{f'}}{10}\right) \quad \text{dB}$$

where

f' = 1/3 octave frequency band contained in octave band f

SPL_f = octave band SPL for band f

$SPL_{f'}$ = 1/3 octave band SPL for band f'

At least two 1/3 octave band SPL were required for each octave otherwise that octave band SPL was not calculated. All three 1/3 octave bands were generally used in computing octave band SPL for the handbook. For those few exceptions, based on two 1/3 octave bands, the calculated octave band SPL will typically be 0-1 dB low, which is not a significant inaccuracy.

A-WEIGHTED AND C-WEIGHTED OVERALL SOUND LEVELS

The human ear is not equally sensitive to sound at all frequencies. Investigators have determined weighting functions[14] which can be used to derive measures of subjective loudness of different spectra. Table 5 lists two such functions that are algebraically added to the measured band SPLs. You then sum the resultant weighted band levels on a power basis to obtain the weighted overall sound level. In the handbook we calculated such weighted sound levels from 1/3 octave band SPL spectra except for those few times where we had only octave band data.

For example, the A-weighted overall sound level (OASLA) is a single-number measure that represents the relative subjective loudness of a particular sound spectrum and is given by:

$$\text{OASLA} = 10 \log \sum_f \text{antilog} \left(\frac{\text{SPL}_f + \text{AW}_f}{10} \right) \quad \text{dBA}$$

where

SPL_f = SPL in frequency band f

AW_f = A-weighting (dB) for band f (Table 5)

The C-weighted overall sound level (OASLC) is a similar weighted measure obtained in exactly the same way except with the C-weighting function. The unit is dBC.

Many publications [15,16,17] describe and discuss the basis and use of these two very common sound levels. Air Force Regulation AFR 161-35[11] uses one or both to specify limiting sound levels and exposure times for personnel and evaluate voice communication capabilities and the effectiveness of ear protectors in different sound fields. The A-weighted overall sound level sometimes is also used to quantify the annoyance or subjective noisiness of different spectra.

PREFERRED SPEECH INTERFERENCE LEVEL

Preferred speech interference level (PSIL) is perhaps the best practical measure available to assess how well people can communicate by voice in a specific noise environment[16,17]. Other measures, such as OASLA also serve this purpose, but PSIL more accurately defines the degree of speech interference as determined by subjective tests. Air Force Regulation AFR 161-35 provides dual scales showing both measures such that OASLA =PSIL+ 7 dB. This relationship is only an approximation. The consistency for evaluating interference with speech for a variety of noises is better for PSIL (standard deviation = 2.8 dB) than for OASLA (4.7 dB)[16].

For any given noise spectrum, PSIL is simply the arithmetic average SPL for three specific, consecutive octave bands.

$$\text{PSIL} = \frac{1}{3} \sum_f \text{SPL}_f$$

where

f = 500, 1000, and 2000 Hz octave bands

SPL_f = octave band SPL in band f

The SPL_f must be defined for all three octave bands or be derivable from 1/3 octave band SPL. Otherwise, the OMEGA programs and handbook omit PSIL for that spectrum.

TABLE 5

WEIGHTING FACTORS[14]

Frequency (Hz)	*Relative Response (dB)*	
	A-Weighting	*C-Weighting*
10	–70.4	–14.3
12.5	–63.4	–11.2
16	–56.7	– 8.5
20	–50.5	– 6.2
25	–44.7	– 4.4
31.5	–39.4	– 3.0
40	–34.6	– 2.0
50	–30.2	– 1.3
63	–26.2	– 0.8
80	–22.5	– 0.5
100	–19.1	– 0.3
125	–16.1	– 0.2
160	–13.4	– 0.1
200	–10.9	– 0
250	– 8.6	– 0
315	– 6.6	– 0
400	– 4.8	– 0
500	– 3.2	– 0
630	– 1.9	– 0
800	– 0.8	– 0
1000	0	0
1250	+ 0.6	0
1600	+ 1.0	– 0.1
2000	+ 1.2	– 0.2
2500	+ 1.3	– 0.3
3150	+ 1.2	– 0.5
4000	+ 1.0	– 0.8
5000	+ 0.5	– 1.3
6300	– 0.1	– 2.0
8000	– 1.1	– 3.0
10,000	– 2.5	– 4.4
12,500	– 4.3	– 6.2
16,000	– 6.6	– 8.5
20,000	– 9.3	–11.2

PERCEIVED NOISE LEVEL AND TONE-CORRECTED PERCEIVED NOISE LEVEL

The perceived noise level (PNL) quantifies the relative subjective noisiness of different sound spectra and is widely used to assess the annoyance of individual sounds [15,18].

To compute the PNL values in the handbook, we applied a standard procedure described in several references[12,19]. PNL is calculated as follows from a particular SPL spectrum:

(1) Convert each 1/3 octave band SPL for the 50 to 10,000 Hz bands (or octave band SPL for the 63 to 8,000 Hz bands) to perceived noisiness n_f, using Table 6, which defines the noisiness of sound in noy units as a function of frequency and SPL for both octave and 1/3 octave bands.

(2) Determine total perceived noisiness N as follows:

For 1/3 octave bands

$$N = 0.85n + 0.15 \sum_f n_f \quad \text{noys}$$

Where

f = 24 bands centered on 1/3 octave frequencies from 50 to 10,000 Hz

n_f = perceived noisiness values from Step (1)

n = number of noys in the noisiest band

For octave bands

$$N = 0.7\,n + 0.3 \sum_f n_f \quad \text{noys}$$

where

f = 8 bands centered on octave frequencies of 63 to 8,000 Hz

n_f and n are the same as above.

(3) Calculate PNL

$$PNL = 40 + 33.3 \log N \quad \text{PNdB}$$

The unit of PNL is the perceived noise decibel, PNdB.

Sound spectra containing significant tones (i.e., sound at one or more discrete frequencies) superimposed on broad band noise are usually judged to be subjectively noisier because of the tones. We used a standard 10-step iterative procedure[12] to calculate a tone correction factor C in dB that estimates the additional noisiness due to tonal content. Appendix B describes this procedure, which requires a 1/3 octave band SPL spectrum for 80 to 10,000 Hz. Before applying this procedure we derived any missing band SPLs by linear interpolation between adjacent values except at the ends of the spectrum. Ten consecutive bands about the peak SPL and with SPL > 20 dB were required for computation of C. If there were less than 10, we flagged the output and printed a footnote on data tables that C was not computed. The value of C can range from 0 to 6.7 dB but typically varied from 0 to 3 dB.

The tone-corrected perceived noise level (PNLT) for any given spectrum was then calculated by:

$$PNLT = PNL + C \quad \text{PNdB}$$

For those few times when our measured data were available only in octave bands, we calculated PNL but not C or PNLT.

TABLE 6
PERCEIVED NOISINESS (NOYS)
AS A FUNCTION OF SPL AND FREQUENCY[19]

SPL (dB)	FREQUENCY (HZ) 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K
4																			.10					
5																		.10	.11	.10				
6																		.11	.12	.11	.10			
7																		.12	.14	.13	.11			
8																		.14	.16	.14	.13			
9																	.10	.16	.17	.16	.14			
10																	.11	.17	.19	.18	.16	.10		
11																	.13	.19	.22	.21	.18	.12		
12																.10	.14	.22	.24	.24	.21	.14		
13																.11	.16	.24	.27	.27	.24	.16		
14																.13	.18	.27	.30	.30	.27	.19		
15															.10	.14	.21	.30	.33	.33	.30	.22		
16										.10	.10	.10	.10	.10	.11	.16	.24	.33	.35	.35	.33	.26		
17										.11	.11	.11	.11	.11	.13	.18	.27	.35	.38	.38	.35	.30	.10	
18									.10	.13	.13	.13	.13	.13	.15	.21	.30	.38	.41	.41	.38	.33	.12	
19									.11	.14	.14	.14	.14	.14	.17	.24	.33	.41	.45	.45	.41	.36	.14	
20								.13	.16	.16	.16	.16	.16	.20	.27	.36	.45	.49	.49	.45	.39	.17		
21								.10	.14	.18	.18	.18	.18	.23	.30	.39	.49	.53	.53	.49	.42	.21	.10	
22								.11	.16	.21	.21	.21	.21	.26	.33	.42	.53	.57	.57	.53	.46	.25	.11	
23								.13	.18	.24	.24	.24	.24	.30	.36	.46	.57	.62	.62	.57	.50	.30	.13	
24							.10	.14	.21	.27	.27	.27	.27	.27	.33	.40	.50	.62	.67	.67	.62	.55	.33	.15
25							.11	.16	.24	.30	.30	.30	.30	.30	.35	.43	.55	.67	.73	.73	.67	.60	.36	.17
26							.13	.18	.27	.33	.33	.33	.33	.33	.38	.48	.60	.73	.79	.79	.73	.65	.39	.20
27						.10	.14	.21	.30	.35	.35	.35	.35	.35	.41	.52	.65	.79	.85	.85	.79	.71	.42	.23
28						.11	.16	.24	.33	.38	.38	.38	.38	.38	.45	.57	.71	.85	.92	.92	.85	.77	.46	.26
29						.13	.18	.27	.35	.41	.41	.41	.41	.41	.49	.63	.77	.92	1.00	1.00	.92	.84	.50	.30
30					.10	.14	.21	.30	.38	.45	.45	.45	.45	.45	.53	.69	.84	1.00	1.07	1.07	1.00	.92	.55	.33
31					.11	.16	.24	.33	.41	.49	.49	.49	.49	.49	.57	.76	.92	1.07	1.15	1.15	1.07	1.00	.60	.37
32					.13	.18	.27	.36	.45	.53	.53	.53	.53	.53	.62	.83	1.00	1.15	1.23	1.23	1.15	1.07	.65	.41
33					.14	.21	.30	.39	.49	.57	.57	.57	.57	.57	.67	.91	1.07	1.23	1.32	1.32	1.23	1.15	.71	.45
34				.10	.16	.24	.33	.42	.53	.62	.62	.62	.62	.62	.73	1.00	1.15	1.32	1.41	1.41	1.32	1.23	.77	.50
35				.11	.18	.27	.36	.46	.57	.67	.67	.67	.67	.67	.79	1.07	1.23	1.41	1.51	1.51	1.41	1.32	.84	.55
36				.13	.21	.30	.40	.50	.62	.73	.73	.73	.73	.73	.85	1.15	1.32	1.51	1.62	1.62	1.51	1.41	.92	.61
37				.15	.24	.33	.43	.55	.67	.79	.79	.79	.79	.79	.92	1.23	1.41	1.62	1.74	1.74	1.62	1.51	1.00	.67
38				.17	.27	.37	.46	.60	.73	.85	.85	.85	.85	.85	1.00	1.32	1.51	1.74	1.86	1.86	1.74	1.62	1.10	.74
39			.10	.20	.30	.41	.52	.65	.79	.92	.92	.92	.92	.92	1.07	1.41	1.62	1.86	1.99	1.99	1.86	1.74	1.21	.82
40			.12	.23	.33	.45	.57	.71	.85	1.00	1.00	1.00	1.00	1.00	1.15	1.51	1.74	1.99	2.14	2.14	1.99	1.86	1.34	.90
41			.14	.26	.37	.50	.63	.77	.92	1.07	1.07	1.07	1.07	1.07	1.23	1.62	1.86	2.14	2.29	2.29	2.14	1.99	1.48	1.00
42			.16	.30	.41	.55	.69	.84	1.00	1.15	1.15	1.15	1.15	1.15	1.32	1.74	1.99	2.29	2.45	2.45	2.29	2.14	1.63	1.10
43			.19	.33	.45	.61	.76	.92	1.07	1.23	1.23	1.23	1.23	1.23	1.41	1.86	2.14	2.45	2.63	2.63	2.45	2.29	1.74	1.21
44		.10	.22	.37	.50	.67	.83	1.00	1.15	1.32	1.32	1.32	1.32	1.32	1.52	1.99	2.29	2.63	2.81	2.81	2.63	2.45	1.98	1.34
45		.12	.26	.42	.55	.74	.91	1.08	1.24	1.41	1.41	1.41	1.41	1.41	1.62	2.14	2.45	2.81	3.02	3.02	2.81	2.63	2.14	1.48
46		.14	.30	.46	.61	.82	1.00	1.16	1.33	1.52	1.52	1.52	1.52	1.52	1.74	2.29	2.63	3.02	3.23	3.23	3.02	2.81	2.29	1.63
47		.16	.34	.52	.67	.90	1.08	1.25	1.42	1.62	1.62	1.62	1.62	1.62	1.87	2.45	2.81	3.23	3.46	3.46	3.23	3.02	2.45	1.79
48		.19	.38	.58	.74	1.00	1.17	1.34	1.53	1.74	1.74	1.74	1.74	1.74	2.00	2.63	3.02	3.46	3.71	3.71	3.46	3.23	2.63	1.98
49	.10	.22	.43	.65	.82	1.08	1.26	1.45	1.64	1.87	1.87	1.87	1.87	1.87	2.14	2.81	3.23	3.71	3.97	3.97	3.71	3.46	2.81	2.18

TABLE 6. (CONTINUED)

SPL (DB)	FREQUENCY (HZ) 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K
50	.12	.26	.49	.72	.90	1.17	1.36	1.56	1.76	2.00	2.00	2.00	2.00	2.00	2.30	3.02	3.46	3.97	4.26	4.26	3.97	3.71	3.02	2.40
51	.14	.30	.55	.80	1.00	1.26	1.47	1.66	1.89	2.14	2.14	2.14	2.14	2.14	2.46	3.23	3.71	4.26	4.56	4.56	4.26	3.97	3.23	2.63
52	.17	.34	.62	.90	1.08	1.36	1.58	1.80	2.03	2.30	2.30	2.30	2.30	2.30	2.64	3.46	3.97	4.56	4.89	4.89	4.56	4.26	3.46	2.81
53	.21	.39	.70	1.00	1.18	1.47	1.71	1.94	2.17	2.46	2.46	2.46	2.46	2.46	2.83	3.71	4.26	4.89	5.24	5.24	4.89	4.56	3.71	3.02
54	.25	.45	.79	1.09	1.28	1.58	1.85	2.09	2.33	2.64	2.64	2.64	2.64	2.64	3.03	3.97	4.56	5.24	5.61	5.61	5.24	4.89	3.97	3.23
55	.30	.51	.89	1.18	1.38	1.71	2.00	2.25	2.50	2.83	2.83	2.83	2.83	2.83	3.25	4.26	4.89	5.61	6.01	6.01	5.61	5.24	4.26	3.46
56	.34	.59	1.00	1.29	1.50	1.85	2.15	2.42	2.69	3.03	3.03	3.03	3.03	3.03	3.48	4.56	5.24	6.01	6.44	6.44	6.01	5.61	4.56	3.71
57	.39	.67	1.09	1.40	1.63	2.00	2.33	2.61	2.88	3.25	3.25	3.25	3.25	3.25	3.73	4.89	5.61	6.44	6.90	6.90	6.44	6.01	4.89	3.97
58	.45	.77	1.18	1.53	1.77	2.15	2.51	2.81	3.10	3.48	3.48	3.48	3.48	3.48	4.00	5.24	6.01	6.90	7.39	7.39	6.90	6.44	5.24	4.26
59	.51	.87	1.29	1.66	1.92	2.33	2.71	3.03	3.32	3.73	3.73	3.73	3.73	3.73	4.29	5.61	6.44	7.39	7.92	7.92	7.39	6.90	5.61	4.56
60	.59	1.00	1.40	1.81	2.08	2.51	2.93	3.26	3.57	4.00	4.00	4.00	4.00	4.00	4.59	6.01	6.90	7.92	8.49	8.49	7.92	7.39	6.01	4.89
61	.67	1.10	1.53	1.97	2.26	2.71	3.16	3.51	3.83	4.29	4.29	4.29	4.29	4.29	4.92	6.44	7.39	8.49	9.09	9.09	8.49	7.92	6.44	5.24
62	.77	1.21	1.66	2.15	2.45	2.93	3.41	3.78	4.11	4.59	4.59	4.59	4.59	4.59	5.28	6.90	7.92	9.09	9.74	9.74	9.09	8.49	6.90	5.61
63	.87	1.32	1.81	2.34	2.65	3.16	3.69	4.06	4.41	4.92	4.92	4.92	4.92	4.92	5.66	7.39	8.49	9.74	10.4	10.4	9.74	9.09	7.39	6.01
64	1.00	1.45	1.97	2.54	2.88	3.41	3.98	4.38	4.73	5.28	5.28	5.28	5.28	5.28	6.06	7.92	9.09	10.4	11.2	11.2	10.4	9.74	7.92	6.44
65	1.11	1.60	2.15	2.77	3.12	3.69	4.30	4.71	5.08	5.66	5.66	5.66	5.66	5.66	6.50	8.49	9.74	11.2	12.0	12.0	11.2	10.4	8.49	6.90
66	1.22	1.75	2.34	3.01	3.39	3.98	4.64	5.07	5.45	6.06	6.06	6.06	6.06	6.06	6.96	9.09	10.4	12.0	12.8	12.8	12.0	11.2	9.09	7.39
67	1.35	1.92	2.54	3.28	3.68	4.30	5.01	5.46	5.85	6.50	6.50	6.50	6.50	6.50	7.46	9.74	11.2	12.8	13.8	13.8	12.8	12.0	9.74	7.92
68	1.49	2.11	2.77	3.57	3.99	4.64	5.41	5.88	6.27	6.96	6.96	6.96	6.96	6.96	8.00	10.4	12.0	13.8	14.7	14.7	13.8	12.8	10.4	8.49
69	1.65	2.32	3.01	3.88	4.33	5.01	5.84	6.33	6.73	7.46	7.46	7.46	7.46	7.46	8.57	11.2	12.8	14.7	15.8	15.8	14.7	13.8	11.2	9.09
70	1.82	2.55	3.28	4.23	4.69	5.41	6.31	6.81	7.23	8.00	8.00	8.00	8.00	8.00	9.19	12.0	13.8	15.8	16.9	16.9	15.8	14.7	12.0	9.74
71	2.02	2.79	3.57	4.60	5.09	5.84	6.81	7.33	7.75	8.57	8.57	8.57	8.57	8.57	9.85	12.8	14.7	16.9	18.1	18.1	16.9	15.8	12.8	10.4
72	2.23	3.07	3.88	5.01	5.52	6.31	7.36	7.90	8.32	9.19	9.19	9.19	9.19	9.19	10.6	13.8	15.8	18.1	19.4	19.4	18.1	16.9	13.8	11.2
73	2.46	3.37	4.23	5.45	5.99	6.81	7.94	8.50	8.93	9.85	9.85	9.85	9.85	9.85	11.3	14.7	16.9	19.4	20.8	20.8	19.4	18.1	14.7	12.0
74	2.72	3.70	4.60	5.94	6.50	7.36	8.57	9.15	9.59	10.6	10.6	10.6	10.6	10.6	12.1	15.8	18.1	20.8	22.3	22.3	20.8	19.4	15.8	12.8
75	3.01	4.06	5.01	6.46	7.05	7.94	9.19	9.85	10.3	11.3	11.3	11.3	11.3	11.3	13.0	16.9	19.4	22.3	23.9	23.9	22.3	20.8	16.9	13.8
76	3.32	4.46	5.45	7.03	7.65	8.57	9.85	10.6	11.0	12.1	12.1	12.1	12.1	12.1	13.9	18.1	20.8	23.9	25.6	25.6	23.9	22.3	18.1	14.7
77	3.67	4.89	5.94	7.65	8.29	9.19	10.6	11.3	11.8	13.0	13.0	13.0	13.0	13.0	14.9	19.4	22.3	25.6	27.4	27.4	25.6	23.9	19.4	15.8
78	4.06	5.37	6.46	8.33	9.00	9.85	11.3	12.1	12.7	13.9	13.9	13.9	13.9	13.9	16.0	20.3	23.9	27.4	29.4	29.4	27.4	25.6	20.8	16.9
79	4.49	5.90	7.03	9.07	9.76	10.6	12.1	13.0	13.6	14.9	14.9	14.9	14.9	14.9	17.1	22.3	25.6	29.4	31.5	31.5	29.4	27.4	22.3	18.1
80	4.96	6.48	7.65	9.85	10.6	11.3	13.0	13.9	14.6	16.0	16.0	16.0	16.0	16.0	18.4	23.9	27.4	31.5	33.7	33.7	31.5	29.4	23.9	19.4
81	5.48	7.11	8.33	10.6	11.3	12.1	13.9	14.9	15.7	17.1	17.1	17.1	17.1	17.1	19.7	25.6	29.4	33.7	36.1	36.1	33.7	31.5	25.6	20.8
82	6.06	7.81	9.07	11.3	12.1	13.0	14.9	16.0	16.9	18.4	18.4	18.4	18.4	18.4	21.1	27.4	31.5	36.1	38.7	38.7	36.1	33.7	27.4	22.3
83	6.70	8.57	9.87	12.1	13.0	13.9	16.0	17.1	18.1	19.7	19.7	19.7	19.7	19.7	22.6	29.4	33.7	38.7	41.5	41.5	38.7	36.1	29.4	23.9
84	7.41	9.41	10.7	13.0	13.9	14.9	17.1	18.4	19.4	21.1	21.1	21.1	21.1	21.1	24.3	31.5	36.1	41.5	44.4	44.4	41.5	38.7	31.5	25.6
85	8.19	10.3	11.7	13.9	14.9	16.0	18.4	19.7	20.8	22.6	22.6	22.6	22.6	22.6	26.0	33.7	38.7	44.4	47.6	47.6	44.4	41.5	33.7	27.4
86	9.05	11.3	12.7	14.9	16.0	17.1	19.7	21.1	22.4	24.3	24.3	24.3	24.3	24.3	27.9	36.1	41.5	47.6	51.0	51.0	47.6	44.4	36.1	29.4
87	10.0	12.1	13.9	16.0	17.1	18.4	21.1	22.6	24.0	26.0	26.0	26.0	26.0	26.0	29.9	38.7	44.4	51.0	54.7	54.7	51.0	47.6	38.7	31.5
88	11.1	13.0	14.9	17.1	18.4	19.7	22.6	24.3	25.8	27.9	27.9	27.9	27.9	27.9	32.0	41.5	47.6	54.7	58.6	58.6	54.7	51.0	41.5	33.7
89	12.2	13.9	16.0	18.4	19.7	21.1	24.3	26.0	27.7	29.9	29.9	29.9	29.9	29.9	34.3	44.4	51.0	58.6	62.7	62.7	58.6	54.7	44.4	36.1
90	13.5	14.9	17.1	19.7	21.1	22.6	26.0	27.9	29.7	32.0	32.0	32.0	32.0	32.0	36.8	47.6	54.7	62.7	67.2	67.2	62.7	58.6	47.6	38.7
91	14.9	16.0	18.4	21.1	22.6	24.3	27.9	29.9	31.8	34.3	34.3	34.3	34.3	34.3	39.4	51.0	58.6	67.2	72.0	72.0	67.2	62.7	51.0	41.5
92	16.0	17.1	19.7	22.6	24.3	26.0	29.9	32.0	34.2	36.8	36.8	36.8	36.8	36.8	42.2	54.7	62.7	72.0	77.2	77.2	72.0	67.2	54.7	44.4
93	17.1	18.4	21.1	24.3	26.0	27.9	32.0	34.3	36.7	39.4	39.4	39.4	39.4	39.4	45.3	58.6	67.2	77.2	82.7	82.7	77.2	72.0	58.6	47.6
94	18.4	19.7	22.6	26.0	27.9	29.9	34.3	36.8	39.4	42.2	42.2	42.2	42.2	42.2	48.5	62.7	72.0	82.7	88.6	88.6	82.7	77.2	62.7	51.0
95	19.7	21.1	24.3	27.9	29.9	32.0	36.8	39.4	42.2	45.3	45.3	45.3	45.3	45.3	52.0	67.2	77.2	88.6	94.9	94.9	88.6	82.7	67.2	54.7
96	21.1	22.6	26.0	29.9	32.0	34.3	39.4	42.2	45.3	48.5	48.5	48.5	48.5	48.5	55.7	72.0	82.7	94.9	102	102	94.9	88.6	72.0	58.6
97	22.6	24.3	27.9	32.0	34.3	36.8	42.2	45.3	48.5	52.0	52.0	52.0	52.0	52.0	59.7	77.2	88.6	102	109	109	102	94.9	77.2	62.7
98	24.3	26.0	29.9	34.3	36.8	39.4	45.3	48.5	52.0	55.7	55.7	55.7	55.7	55.7	64.0	82.7	94.9	109	117	117	109	102	82.7	67.2
99	26.0	27.9	32.0	36.8	39.4	42.2	48.5	52.0	55.7	59.7	59.7	59.7	59.7	59.7	68.6	88.6	102	117	125	125	117	109	88.6	72.0

TABLE 6. (CONCLUDED)

SPL (DB)	FREQUENCY (HZ) 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K
100	27.9	29.9	34.3	39.4	42.2	45.3	52.0	55.7	59.7	64.0	64.0	64.0	64.0	64.0	73.5	94.9	109	125	134	134	125	117	94.9	77.2
101	29.9	32.0	36.8	42.2	45.3	48.5	55.7	59.7	64.0	68.6	68.6	68.6	68.6	68.6	78.8	102	117	134	144	144	134	125	102	82.7
102	32.0	34.3	39.4	45.3	48.5	52.0	59.7	64.0	68.6	73.5	73.5	73.5	73.5	73.5	84.4	109	125	144	154	154	144	134	109	88.6
103	34.3	36.8	42.2	48.5	52.0	55.7	64.0	68.6	73.5	78.8	78.8	78.8	78.8	78.8	90.5	117	134	154	165	165	154	144	117	94.9
104	36.8	39.4	45.3	52.0	55.7	59.7	68.6	73.5	78.8	84.4	84.4	84.4	84.4	84.4	97.0	125	144	165	177	177	165	154	125	102
105	39.4	42.2	48.5	55.7	59.7	64.0	73.5	78.8	84.4	90.5	90.5	90.5	90.5	90.5	104	134	154	177	189	189	177	165	134	109
106	42.2	45.3	52.0	59.7	64.0	68.6	78.8	84.4	90.5	97.0	97.0	97.0	97.0	97.0	111	144	165	189	203	203	189	177	144	117
107	45.3	48.5	55.7	64.0	68.6	73.5	84.4	90.5	97.0	104	104	104	104	104	119	154	177	203	217	217	203	189	154	125
108	48.5	52.0	59.7	68.6	73.5	78.8	90.5	97.0	104	111	111	111	111	111	128	165	189	217	233	233	217	203	165	134
109	52.0	55.7	64.0	73.5	78.8	84.4	97.0	104	111	119	119	119	119	119	137	177	203	233	249	249	233	217	177	144
110	55.7	59.7	68.6	78.8	84.4	90.5	104	111	119	128	128	128	128	128	147	189	217	249	267	267	249	233	189	154
111	59.7	64.0	73.5	84.4	90.5	97.0	111	119	128	137	137	137	137	137	158	203	233	267	286	286	267	249	203	165
112	64.0	68.6	78.8	90.5	97.0	104	119	128	137	147	147	147	147	147	169	217	249	286	307	307	286	267	217	177
113	68.6	73.5	84.4	97.0	104	111	128	137	147	158	158	158	158	158	181	233	267	307	329	329	307	286	233	189
114	73.5	78.8	90.5	104	111	119	137	147	158	169	169	169	169	169	194	249	286	329	352	352	329	307	249	203
115	78.8	84.4	97.0	111	119	128	147	158	169	181	181	181	181	181	208	267	307	352	377	377	352	329	267	217
116	84.4	90.5	104	119	128	137	158	169	181	194	194	194	194	194	223	286	329	377	404	404	377	352	286	233
117	90.5	97.0	111	128	137	147	169	181	194	208	208	208	208	208	239	307	352	404	433	433	404	377	307	249
118	97.0	104	119	137	147	158	181	194	208	223	223	223	223	223	256	329	377	433	464	464	433	404	329	267
119	104	111	128	147	158	169	194	208	223	239	239	239	239	239	274	352	404	464	497	497	464	433	352	286
120	111	119	137	158	169	181	208	223	239	256	256	256	256	256	294	377	433	497	533	533	497	464	377	307
121	119	128	147	169	181	194	223	239	256	274	274	274	274	274	315	404	464	533	571	571	533	497	404	329
122	128	137	158	181	194	208	239	256	274	294	294	294	294	294	338	433	497	571	611	611	571	533	433	352
123	137	147	169	194	208	223	256	274	294	315	315	315	315	315	362	464	533	611	655	655	611	571	464	377
124	147	158	181	208	223	239	274	294	315	338	338	338	338	338	388	497	571	655	702	702	655	611	497	404
125	158	169	194	223	239	256	294	315	338	362	362	362	362	362	416	533	611	702	752	752	702	655	533	433
126	169	181	208	239	256	274	315	338	362	388	388	388	388	388	446	571	655	752	806	806	752	702	571	464
127	181	194	223	256	274	294	338	362	388	416	416	416	416	416	478	611	702	806	863	863	806	752	611	497
128	194	208	239	274	294	315	362	388	416	446	446	446	446	446	512	655	752	863	925	925	863	806	655	533
129	208	223	256	294	315	338	388	416	446	478	478	478	478	478	549	702	806	925	991	991	925	863	702	571
130	223	239	274	315	338	362	416	446	478	512	512	512	512	512	588	752	863	991	1062	1062	991	925	752	611
131	239	256	294	338	362	388	446	478	512	549	549	549	549	549	630	806	925	1062	1137	1137	1062	991	806	655
132	256	274	315	362	388	416	478	512	549	588	588	588	588	588	676	863	991	1137	1219	1219	1137	1062	863	702
133	274	294	338	388	416	446	512	549	588	630	630	630	630	630	724	925	1062	1219	1306	1306	1219	1137	925	752
134	294	315	362	416	446	478	549	588	630	676	676	676	676	676	776	991	1137	1306	1399	1399	1306	1219	991	806
135	315	338	388	446	478	512	588	630	676	724	724	724	724	724	832	1062	1219	1399	1499	1499	1399	1306	1062	863
136	338	362	416	478	512	549	630	676	724	776	776	776	776	776	891	1137	1306	1499	1606	1606	1499	1399	1137	925
137	362	388	446	512	549	588	676	724	776	832	832	832	832	832	955	1219	1399	1606	1721	1721	1606	1499	1219	991
138	388	416	478	549	588	630	724	776	832	891	891	891	891	891	1024	1306	1499	1721	1843	1843	1721	1606	1306	1062
139	416	446	512	588	630	676	776	832	891	955	955	955	955	955	1097	1399	1606	1843	1975	1975	1843	1721	1399	1137
140	446	478	549	630	676	724	832	891	955	1024	1024	1024	1024	1024	1176	1499	1721	1975			1975	1843	1499	1219
141	478	512	588	676	724	776	891	955	1024	1097	1097	1097	1097	1097	1261	1606	1843					1975	1606	1306
142	512	549	630	724	776	832	955	1024	1097	1176	1176	1176	1176	1176	1351	1721	1975						1721	1399
143	549	588	676	776	832	891	1024	1097	1176	1261	1261	1261	1261	1261	1448	1843							1843	1499
144	588	630	724	832	891	955	1097	1176	1261	1351	1351	1351	1351	1351	1552	1975							1975	1606
145	630	676	776	891	955	1024	1176	1261	1351	1448	1448	1448	1448	1448	1663									1721
146	676	724	832	955	1024	1097	1261	1351	1448	1552	1552	1552	1552	1552	1783									1843
147	724	776	891	1024	1097	1176	1351	1448	1552	1663	1663	1663	1663	1663	1911									1975
148	776	832	955	1097	1176	1261	1448	1552	1663	1783	1783	1783	1783	1783	2048									
149	832	891	1024	1176	1261	1351	1552	1663	1783	1911	1911	1911	1911	1911										
150	891	955	1097	1261	1351	1448	1663	1783	1911	2048	2048	2048	2048	2048										

Far-field PNLT values reported in the handbook for aircraft contain smoothed tone corrections based on procedures described in Reference 7. We applied such smoothing to avoid possible slight irregularities in the PNLT versus distance function caused at one or more distances by tone corrections that reflect false (pseudo) tones. The procedure used to derive a smooth tone correction—distance function for a given angle θ follows:

(1) Calculate C for the spectrum at a distance of 76 meters (250 feet).

(2) Use this C value to derive PNLT at all far-field distances out to 960 meters (3150 feet).

(3) Set C = zero at 3049 meters (10,000 feet).

(4) For distances between 960 and 3049 meters, linearily interpolate C on a log-distance scale between C values at 960 and 3049 meters. Use these interpolated C values to derive PNLT at these intermediate distances.

(5) Use C = zero to derive PNLT for all distances ≥ 3049 meters.

We used unsmoothed C values (i.e., C values based on calculated spectra at different distances) for AGE and other non-aircraft sources reported in the handbook, because the rationale[7] for smoothing C is based only on studies of aircraft noise.

ACOUSTIC POWER LEVEL

Acoustic power level (PWL) is a basic physical measure that defines the acoustic power (W) emitted by a source:

$$PWL_f = 10 \log \frac{W_f}{W_{ref}} \quad \text{dBp}$$

where

PWL_f = acoustic power level in decibels power (dBp) for frequency band f

W_f = effective acoustic power in watts for band f

W_{ref} = reference effective acoustic power = 10^{-12} watt

substituting W_{ref},

$$PWL_f = 10 \log W_f + 120 \quad \text{dBp}$$

conversely,

$$W_f = \text{antilog} \left[\frac{PWL_f - 120}{10} \right] \quad \text{watts}$$

The overall PWL defines the total acoustic power and is calculated by summing the power in all the individual bands:

$$\text{Overall PWL} = 10 \log \sum_f \text{antilog} \left[\frac{PWL_f}{10} \right] \quad \text{dBp}$$

The acoustic power produced by a source on the ground radiates outward and passes through the surface of an imaginery hemisphere centered over the source. If the radius of this hemisphere is sufficiently large so that the surface lies in the acoustic far-field, then one can calculate the source power from the sound pressure distribution over this surface. At each point on the surface, the sound intensity is directly proportional to the squared sound pressure at that point and inversely proportional to the characteristic impedance of the air. Since sound intensity defines the acoustic power per unit area passing through the surface at

that point, the total acoustic power radiated through the surface is the sum of all the incremental intensity x area products over the entire surface. Several references describe these relationships in more detail.[20,21]

The handbook presents overall and band PWL for all aircraft that we measured in the far-field. Such sound fields were rotationally symmetric with respect to aircraft/engine centerline. This means that our measured far-field SPL sufficiently defined the sound pressure for all points on the hemispherical surface. In contrast, AGE sound fields were not symmetric and we would have had to measure the SPL on the surrounding hemisphere at 5 to 10 times as many locations. We did not believe that PWL information on AGE justified that much greater effort.

In calculating PWL we took into account the measured far-field SPL, geometric dispersion and the characteristic impedance of the air. We also corrected for atmospheric absorption losses and excess attenuation effects that occurred between the source and the measurement locations:

$$PWL_f = \frac{[D_o]\,[ATNR_f]}{100} + EA_{D_o,f} + 10 \log \left[\frac{(K)\,(D_o)^2}{IMP} \right]$$

$$-14 + 10 \log \sum_{\theta} [S_\theta] \left(\text{antilog} \ \frac{SPL_{D_o,\theta,f}}{10} \right) \qquad \text{dBp}$$

where

PWL_f = acoustic power level in decibels power, dBp, contained in frequency band f

D_o = distance in meters

$ATNR_f$ = sound absorption coefficients* in dB per 100 meters for each band f for the test site temperature and humidity.

$EA_{D_o,f}$ = excess attenuation* in dB for distance D_o and band f.

K = 2 for cases when source measured was on the ground which was true for all far-field data in handbook.

IMP = characteristic impedance of air in mks rayls

$$IMP = \left[\frac{273}{273 + T} \right]^{1/2} \left[\frac{P_o\,(428.6)}{0.760} \right]$$

T_o = temperature at test site in degrees C

P_o = barometric pressure at test site in meters Hg

*Discussed later under section entitled, Normalization and Extrapolation of Far-Field Noise Data

θ = angle in degrees from source at which SPL was measured (specifically one of the 19 standard measurement angles 0, 10, 20 . . . 180 degrees)

S_θ = area function listed in Table 7 used to compute area of incremental half-ring surfaces on hemisphere corresponding to specific θ angles[22]. SPL is assumed constant over each half-ring surface.

$SPL_{D_o, \theta, f}$ = SPL measured under field test conditions at distance D_o and angle θ for frequency band f.

TABLE 7

AREA FUNCTION S_θ [22] USED IN CALCULATION OF PWL

Angle θ (Degrees)	*S Value (Dimensionless)*
0 and 180	59.8
10 and 170	475.5
20 and 160	936.5
30 and 150	1369.0
40 and 140	1760.0
50 and 130	2097.5
60 and 120	2371.2
70 and 110	2573.0
80 and 100	2696.5
90	2738.1

DIRECTIVITY INDEX

Although the PWL defines the acoustic power emitted by a source, it does not describe how much of that power radiates in any particular direction. The directivity index (DI) describes the directionality of a source in a standard way, useful to study source characteristics and compare different sources.

The DI is the difference between the actual far-field SPL measured at some angle and distance from a source and a hypothetical SPL (sometimes called the space-average sound pressure level, SASPL) which would be produced at the same point under the same test conditions by another source which had exactly the same power but radiated uniformly in all directions.[20] Specifically, the directivity index for a frequency band is

$$DI_{\theta,f} = SPL_{D_o,\theta,f} - SASPL_{D_o,f} \quad \text{dB}$$

where

$DI_{\theta,f}$ = directivity index in dB for angle θ and frequency band f.

$SPL_{D_o,\theta,f}$ = SPL in dB measured at distance D_o and angle θ for band f.

$SASPL_{D_o,f}$ = Space average SPL in dB for distance D_o and band f

$$= 10 \log \left\{ \sum_{\theta=0}^{180} [S_\theta] \left[\text{antilog} \left(\frac{SPL_{D_o,\theta,f}}{10} \right) \right] \right\} - 45 \quad \text{dB}$$

S_θ = area function listed in Table 7 and discussed under PWL subsection

Similarly, the overall DI is the difference between the actual far-field OASPL measured at some angle θ and distance D_o and an overall SASPL that would be produced at the same angle and distance by a nondirectional source of the same power. For any far-field distance:

$$\text{Overall } DI_\theta = OASPL_{D_o,\theta} - [\text{Overall } SASPL_{D_o}] \quad \text{dB}$$

where

Overall DI_θ = Overall directivity index in dB for angle θ.

$OASPL_{D_o,\theta}$ = Overall SPL in dB measured at distance D_o and angle θ.

$$\text{Overall } SASPL_{D_o} = 10 \log \sum_f \text{antilog} \left[\frac{SASPL_{D_o,f}}{10} \right] \quad \text{dB}$$

The foregoing discussions on PWL and DI give the defining equations, but only minimally describe these quantities, their derivation, and inter-relationships. We expect that the primary users of such handbook data will be acoustical engineers, noise control specialists, or others who are familiar with these basic measures of source output.

NOISE EXPOSURE LIMITS

HEARING

AFR 161-35[11] sets forth exposure limits for the protection of hearing in terms of the A-weighted overall sound level (OASLA) and length of time exposed daily. Figure 4 gives the limiting values specified for total daily exposure based on the actual sound level reaching the ear. Table 8 lists these time limits for specific integer values of OASLA. These limits directly apply when the noise exposure occurs each workday at only one specified level. The regulation (para. 20.b) also specifies procedures to determine if intermittent, multi-level exposures during a workday exceed these limiting values for total daily exposure.

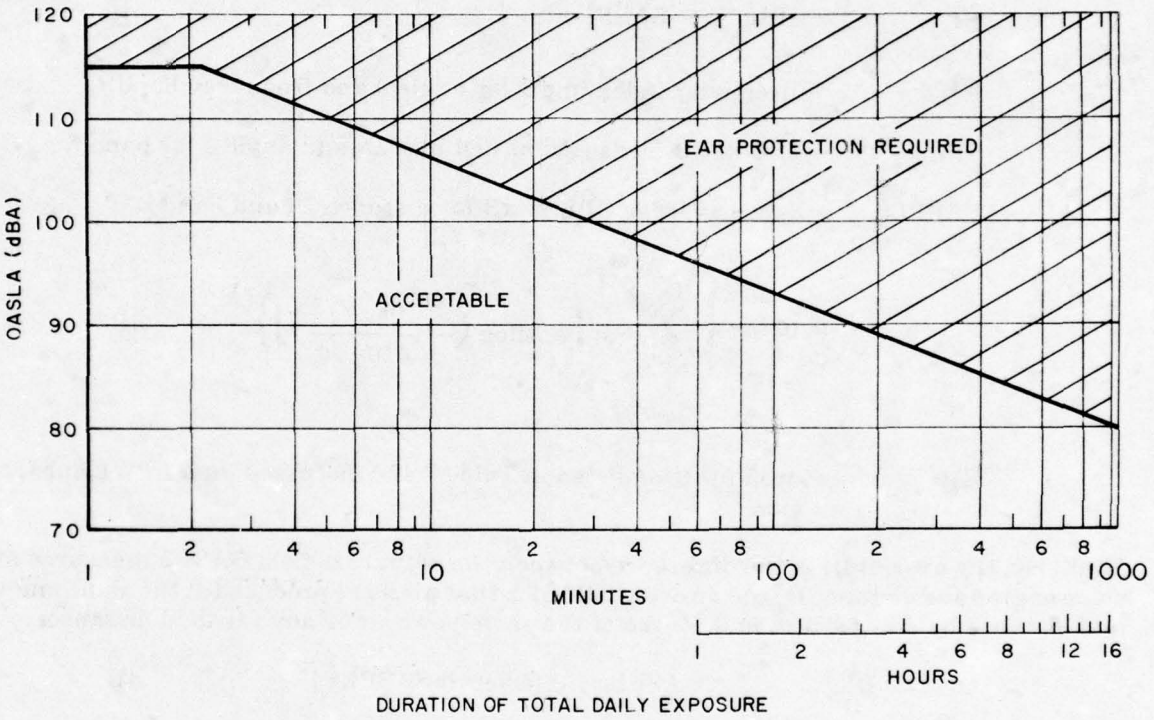

Figure 4. Noise Exposure Limits — Hearing — Limiting Values for Total Daily Exposure, AFR 161-35[11]

The noise level-time patterns of noise exposure experienced daily by Air Force personnel vary greatly and depend on individual situations. Consequently, the handbook defines noise levels at specific locations for specific operations, but cannot provide information on any individual person's exposure time history. For example, the exposures of ground crew are generally complex, intermittent at different levels, and variable from one work situation to the next. By contrast, some particular flight crew exposures are relatively uniform during most of a mission. Each situation must be evaluated by observing or estimating how long personnel typically occupy specific locations during specific operations. One can then use the handbook or other source to determine the sound levels involved in that exposure and apply AFR 161-35 to calculate corresponding time limits on daily exposure or determine requirements for ear protectors.

TABLE 8

NOISE EXPOSURE LIMITS — HEARING—
LIMITING VALUES FOR TOTAL DAILY EXPOSURE — AFR 161-35[11]

Duration of Total Daily Exposure time (T)
As A function of A-Weighted Overall Sound Level (OASLA)

OASLA (dBA)	*T* (Minutes)*	*OASLA (dBA)*	*T* (Minutes)*
Above 115	*Ear Protection Required*		
115	2.2	95	71
114	2.7	94	85
113	3.2	93	101
112	3.8	92	120
111	4.5	91	143
110	5	90	170
109	6	89	202
108	8	88	240
107	9	87	285
106	11	86	339
105	13	85	404
104	15	84	480
103	18	83	571
102	21	82	679
101	25	81	807
100	30	80	960
99	36		
98	42	Below 80	960**
97	50		
96	60		

*Rounded to nearest 0.1 below 5 minutes and nearest integer above 5 minutes.

**The handbook does not extend T beyond 16 hours.

The handbook gives the limiting time for one (or total) exposure per workday to the specific sound levels reported. Such information is relevant and useful for certain exposure situations; e.g., whenever daily exposure is controlled by continuous or intermittent exposure to one specific noise level; or for cases of exposure to a very high noise level that controls the daily exposure allowed, despite exposure to lower levels. Experience in evaluating ODD/LDD ratios for multiple daily exposure in accordance with AFR 161-35, para 20.b enables recognition of those conditions where the time limits presented in the handbook for total daily exposure to a specific sound level are applicable.

If the OASLA exceeds 115 dBA for any given noise environments reported, then the handbook indicates that ear protection is required.

PERFORMANCE

In many USAF work environments, persons encounter noise exposure that degrades job performance. These noise exposures may or may not impair the unprotected ear.

AFR 161-35 (para. 21) provides noise exposure limits directed toward helping maintain effective job performance. These limits concern effective person-to-person voice communication (conversations), the quality of such communication, and criteria for offices and work spaces. These limits are specified in terms of preferred speech interference level (PSIL) and A-weighted overall sound level (OASLA).

These limits can be used to evaluate job performance for the noise exposure situations reported in the handbook, which provides the required PSIL and OASLA data.

WHOLE BODY EFFECTS

Persons exposed to high-level sound can experience adverse effects that do not depend on the hearing organs. AFR 161-35, para. 22, specifies noise exposure limits for such whole body effects for several frequency ranges in terms of OASLA, 1/3 octave band SPL, and maximum exposure times permissible each workday. In general, these limits permit exposures of unlimited duration up to specific noise levels, then put maximum total time limits on daily exposure at those critical noise levels, and finally prohibit any exposure above those critical levels.

AMRL has extrapolated these criteria to lower levels as shown in Figure 5 whereby we kept the same critical levels and maximum times, but identified limiting times for lower noise levels using a –4 dB per double time tradeoff in a fashion analogous to the auditory criteria. We believe that these extrapolated criteria are more realistic yet conservative in that they further protect personnel.

We also added a limit so that exposure to any band SPL above 150 dB, 100-10,000 Hz, is unacceptable. This protects against exposure to high levels at those frequencies where band levels could otherwise be much higher than 150 dB while the corresponding OASLA remained within an acceptable range. For example, a spectrum with 160 dB in the 100 Hz, 1/3 octave band SPL, and 135 dB or less in other bands would have an OASLA less than 150 dBA because the A-weighting factor at 100 Hz is –19 dB.

The special limit of 85 dB, Figure 5, in the 12,500 — 40,000 Hz range, applies to high-frequency/ultrasonic spectra with discrete-frequency tones. Ear protection is required above this limit to avoid adverse **subjective** effects. AFR 161-35, para. 22.c. identifies this 85 dB limit but does not clarify that it only applies to spectra with significant high-frequency/ultrasonic tones (e.g., tones at least 6 dB above the broad band noise at adjacent frequencies) as typically encountered with ultrasonic cleaners and other such devices. Most aircraft and AGE reported in the handbook do not have significant tonal content in this ultrasonic range. Hence, **we do not apply this special limit to most handbook data.** We extend the frequency range and apply this special limit for any ultrasonic device reported in the handbook.

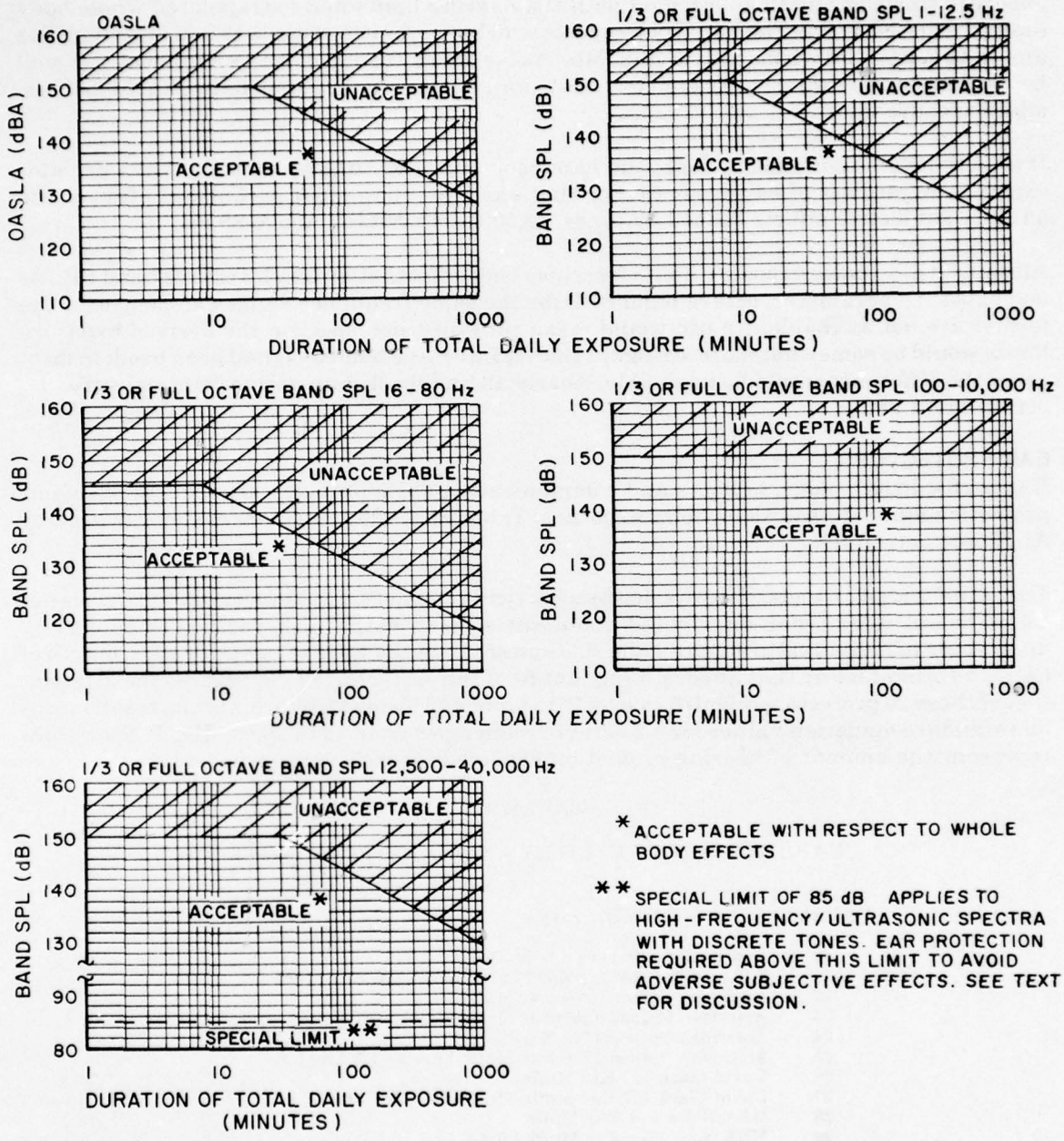

Figure 5. Noise Exposure Limits — Whole Body Effects — AFR 161-35 Limits Extrapolated to Lower Levels

For each noise environment reported in the handbook, we calculated the maximum daily exposure times permissible based on both the hearing limits and extrapolated whole body limits discussed above. The handbook reports whichever limiting time was less and identifies any time set by the whole body limits. Most noise levels reported in the handbook are well below limits set by whole body effects. Limits for hearing protection usually control permissible exposure times.

If a noise level is sufficiently high, the handbook indicates that whole body limits prohibit exposure regardless of ear protection or that ear protection must be worn to prevent the adverse subjective effects caused by tones, 12,500 — 40,000 Hz, above 85 dB.

Although these noise exposure limits for whole body effects stipulate 1/3 octave band SPL as one exposure parameter, octave band SPL for the same frequency range can be used if the former are not available. Its use would mean that for some spectra, the derived exposure limits would be somewhat more stringent than if 1/3 octave band SPL had been used; in most cases the difference would be negligible. Nearly all handbook data derive from measured 1/3 octave band SPL.

EAR PROTECTORS

Ear muffs, insert plugs, helmets and communication units provide various degrees of ear protection against hazardous noise exposure. Table 9 lists 20 protectors commonly used by Air Force personnel.

The actual sound attenuation provided by a particular model protector worn in the field is not constant but is gaussian-distributed about some mean value with variability caused by differences in individual protectors, the size and shape of the wearer's head or ears, length of hair, and other factors that affect subsequent fit of the protector. Table 10 gives the attenuation of these 20 protectors (identifiable by PD number on Table 9) in terms of the mean minus one standard deviation values for 1/3 octave frequencies from 10 to 20,000 Hz. These values represent the amount of hearing protection expected for 85% of the wearers.

TABLE 9

EAR PROTECTORS USED BY AIR FORCE PERSONNEL

*PD NUMBER**	*DESCRIPTION*
20	Willson 258 (Sponge) Ear Muffs
21	Willson 258 (Sponge) Ear Muffs Plus V-51R Ear Plugs
22	American Optical 1200 Ear Muffs
23	American Optical 1200 Ear Muffs Plus V-51R Ear Plugs
24	American Optical 1700 Ear Muffs
25	American Optical 1700 Ear Muffs Plus V-51R Ear Plugs
26	David Clark 117 Ear Muffs
27	David Clark 117 Ear Muffs Plus V-51R Ear Plugs
28	MSA Noise Foe Ear Muffs
29	MSA Noise Foe Ear Muffs Plus V-51R Ear Plugs
30	Minimum QPL Ear Muffs
31	V-51R Ear Plugs
32	Flents Ear Plugs
33	HGU-2A/P Helmet With H-154
34	HGU-2A/P Helmet With 17P Liner
36	HGU-2A/P Helmet With Custom Liner
37	H-133 Ground Communication Unit
38	H-157 In-flight Communication Unit
41	Comfit Triple Flange Ear Plugs
42	HGU-2A/P Helmet With H-154(A)

*Protective Device Number Used by AMRL To Identify Protectors

TABLE 10

ATTENUATION (dB) OF EAR PROTECTORS*

Frequency	*PD Number*																			
(Hz)	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*36*	*37*	*38*	*41*	*42*
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
20	0	5	0	3	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
25	0	8	0	6	0	8	0	8	0	2	0	1	0	0	0	0	0	0	0	0
31.5	0	11	0	9	0	11	0	11	0	5	0	4	2	0	0	0	0	0	3	0
40	0	14	0	12	0	14	0	14	0	8	0	7	5	0	0	0	2	0	6	0
50	0	17	0	15	0	17	1	17	0	11	0	10	8	0	0	0	5	0	9	0
63	0	20	0	18	1	20	4	20	2	14	0	13	11	0	0	0	8	0	12	0
80	0	23	0	21	4	23	7	23	5	17	0	16	14	0	0	0	11	0	15	0
100	2	26	3	24	7	26	10	26	8	20	2	19	17	0	0	0	14	3	18	3
125	5	29	6	27	10	29	13	29	11	23	5	22	20	0	0	0	17	6	21	6
160	8	32	11	30	13	32	16	32	14	28	8	21	20	0	0	0	20	7	21	5
200	12	34	15	33	16	35	18	35	18	33	12	21	19	0	0	0	23	8	20	4
250	15	37	19	36	19	37	21	36	21	36	15	20	19	0	0	0	26	10	20	4
315	18	40	22	38	21	39	27	36	25	38	17	20	19	3	1	1	31	13	20	6
400	22	42	24	40	24	39	34	35	29	38	18	21	21	7	6	2	37	17	20	13
500	26	43	25	41	26	39	36	35	31	38	20	22	22	11	10	3	39	20	20	17
630	31	43	29	41	30	38	37	35	30	36	23	23	23	14	13	3	36	23	20	18
800	38	42	36	39	35	37	37	35	29	32	28	23	24	18	15	4	28	25	21	19
1000	40	42	38	39	36	36	37	36	29	30	30	24	25	20	17	4	26	26	21	20
1250	40	42	38	40	36	38	36	36	31	32	30	26	27	23	18	5	27	26	22	22
1600	39	42	38	44	36	44	34	37	35	36	30	30	29	25	18	9	28	25	24	26
2000	38	43	38	47	36	47	33	38	37	39	30	33	32	26	20	14	29	25	25	30
2500	39	46	41	45	36	46	33	42	33	41	30	34	35	26	24	20	25	25	24	34
3150	41	49	44	44	36	46	34	50	31	44	30	33	36	24	30	29	24	26	22	39
4000	42	50	34	52	38	54	35	52	37	45	30	29	34	22	37	38	33	32	21	43
5000	40	47	35	48	41	44	33	50	35	44	25	31	33	18	39	34	33	32	26	43
6300	36	41	36	42	42	40	33	45	32	40	25	33	31	14	39	30	32	30	30	41
8000	32	37	30	39	27	40	39	38	29	29	25	31	30	10	31	29	31	27	30	32
10000	29	34	27	36	24	37	36	35	26	26	22	28	27	7	28	26	28	24	27	29
12500	26	31	24	33	21	34	33	32	23	23	19	25	24	4	25	23	25	21	24	26
16000	23	28	21	30	18	31	30	29	20	20	16	22	21	1	22	20	22	18	21	23
20000	20	25	18	27	15	28	27	26	17	17	13	19	18	0	19	17	19	15	18	20

*Values represent the minimum attenuation (mean minus one standard deviation) expected for 85% of the wearers. Values are based on measured data[11] at 9 frequencies ranging from 125 to 8,000 Hz.

We derived these values from data presented in attachment 9 of AFR 161-35, which were the result of extensive measurements made at nine frequencies over a range from 125 to 8,000 Hz. We interpolated values at intermediate 1/3 octave band center frequencies using a smooth curve fit to the 9 measured points. For frequencies below 125 Hz, we took the attenuation at 125 Hz and decreased it 3 dB for each 1/3 octave decrease in frequency. Above 8,000 Hz we started with the value at 8,000 Hz and decreased it 3 dB for each 1/3 octave increase in frequency. At no time did we extrapolate below 0 dB; i.e., to derive negative attenuation values, which would mean the protector increased the level at the ear.

I have already stated that the handbook gives the limiting times for one (or total) exposure per workday of an unprotected person to the specific sound levels reported. The handbook also provides similar limiting times applicable for personnel wearing the particular protectors listed in Table 11. We selected these protectors as representative of those most commonly used in several different exposure situations.

TABLE 11

EAR PROTECTORS COMMONLY USED IN DIFFERENT EXPOSURE SITUATIONS FOR WHICH THE HANDBOOK PROVIDES LIMITING EXPOSURE TIMES

IN-FLIGHT NOISE (Flight Crew/Passengers)
Fighter Aircraft
HGU-2A/P Helmet With H-154
HGU-2A/P Helmet With H-154(A)
HGU-2A/P Helmet With Custom Liner

Bomber/Cargo/Transport Aircraft
Minimum QPL Ear Muffs
V-51R Ear Plugs
Flents Ear Plugs
H-157 In-Flight Communication Unit

Helicopter Aircraft
HGU-2A/P Helmet With H-154
HGU-2A/P Helmet With H-154(A)
HGU-2A/P Helmet With Custom Liner
V-51R Ear Plugs
H-157 In-Flight Communication Unit

NEAR-FIELD NOISE (Ground Crew)
Minimum QPL Ear Muffs
American Optical 1700 Ear Muffs
V-51R Ear Plugs
American Optical 1700 Ear Muffs Plus V-51R Ear Plugs
H-133 Ground Communication Unit

FAR-FIELD NOISE (Flight Line)
Minimum QPL Ear Muffs
American Optical 1700 Ear Muffs
V-51R Ear Plugs
Comfit Triple Flange Ear Plugs
H-133 Ground Communication Unit

The procedure used throughout the handbook to calculate the limiting exposure time with an ear protector was to, first, derive the SPL spectrum at the ear under the device by subtracting the attenuation values of Table 10 from the SPL spectrum outside the protector (i.e., for the location and test condition of interest); next, calculate the A-weighted overall sound level (OASLA) from that spectrum; and then, determine the limiting time for one (or total) exposure per workday based on this OASLA at the ear in accordance with Figure 4. This procedure is more accurate than if we had used the approximate sound attenuation data in AFR 161-35, para. 15.b., which specifies the effectiveness of protectors in terms of OASLA reduction as a function of the difference between OASLC and OASLA of the environment present.

Exposure time limits set by whole body effects were derived independently of limits set by effects on hearing either with or without ear protectors. The handbook reports whichever limiting time was less and identifies any time limit set by whole body effects.

NORMALIZATION AND EXTRAPOLATION OF FAR-FIELD NOISE DATA

PURPOSE

Measured far-field data describe the noise at specific locations for those meteorological conditions present at the time. We measured few if any sources under the same set of conditions. The handbook not only reports the actual measured SPL and field test conditions, but also presents normalized far-field data corrected to those levels expected at a standard reference distance (10 meters for AGE, 100 meters for aircraft) under standard reference meteorological conditions (15 C temperature, 0.760 meter Hg barometric pressure, 70% relative humidity). **These normalized data enable direct comparison of noise produced by different sources of the same class**; i.e., aircraft-to-aircraft or AGE-to-AGE.

We also extrapolated the measured data over a range of far-field distances to derive equal value contours presented in the handbook for seven noise measures described earlier. **These contours enable the reader to easily determine estimated levels and limiting exposure times at any angle and reasonable distance from the source.** The handbook contours apply for the standard reference meteorology and are sufficiently accurate for many real-life field situations. Volume 2[10] provides information on the effects of meteorology and their significance and also provides procedures and data to adjust the handbooks' standard far-field contours for nonstandard meteorological conditions if necessary.

PROCEDURE

The relationship used to normalize and extrapolate the measured SPL follows:

$$SPL_{D_k,\,\theta,\,f} = SPL_{D_o,\,\theta,\,f} + 10\log\,[IMPR] + 20\log\left[\frac{D_o}{D_k}\right] + \frac{D_o\,[ATNR_f]}{100} - \frac{D_k\,[ATNC_f]}{100} + EA_{D_o,\,f} - EA_{D_k,\,f} \quad \text{dB}$$

where

$SPL_{D_k,\,\theta,\,f}$ = calculated band SPL in decibels (dB) at distance D_k and angle θ from the source for frequency band f.

$SPL_{D_o,\,\theta,\,f}$ = measured band SPL in dB at distance D_o and angle θ from the source for band f.

$$IMPR = \text{characteristic impedance ratio} = \left[\left(\frac{273 + T_o}{273 + T_i}\right)^{1/2}\left(\frac{P_i}{P_o}\right)\right]$$

T_o = temperature at test site in degrees C

T_1 = standard reference temperature = 15 C

P_o = barometric pressure at test site in meters Hg

P_1 = standard reference barometric pressure = 0.760 meter Hg

D_o = distance in meters from source to measurement location during field tests

D_k = distance in meters from source to location of interest

$ATNR_f$ = sound absorption coefficient in dB/100 meters for frequency band *f* for test site temperature T_o and relative humidity H_o.

$ATNC_f$ = same as above except applies for the reference temperature T_1 (15 C) and reference relative humidity H_1 (70%).

$EA_{D_o,f}$ = excess attenuation of sound in dB over distance D_o for frequency band *f*.

$EA_{D_k,f}$ = same as above except applies over distance D_k.

The term involving IMPR is not frequency-dependent and accounts for differences in SPL caused by sound velocity and air density differences for standard reference versus field test conditions.

The third term which involves the D_o/D_k ratio also does not depend on frequency and corrects for differences in geometric dispersion of the diverging sound for the two distances. The far-field sound pressure is inversely proportional to the square of the distance from the source, which means the SPL decreases 6 dB per doubling of distance due to geometric dispersion alone.

The two terms with ATNR and ATNC account for differences in sound absorption by the atmosphere caused by differences in meteorology between field test and standard reference conditions. The magnitude of these sound absorption losses depend primarily on frequency, temperature, and relative humidity. Volume 2 discusses and lists these coefficients, which are based on current, nationally accepted practices[23].

The remaining two terms correct for differences in excess attenuation (EA) for the two different propagation distances, D_o and D_k. This EA (Figure 6) depends on frequency and propagation distance and accounts for attenuation of sound in excess of attenuation caused by air absorption and simple geometric dispersion. Sound absorption by ground cover (e.g., grass, trees), sound scattering by air turbulence, sound refraction by temperature and wind velocity gradients and other factors contribute to EA.

These EA values came from the results of experimental studies [24] on noise propagating along the earth's surface, and were recommended in modified form [7] by the original investigator for use in predicting community noise exposure resulting from aircraft operations. AMRL extrapolated these results to several additional 1/3 octave frequency bands (specifically 16, 20, 25, 31.5 and 40 Hz) to prevent unrealistic discontinuities in derived SPL spectra. These average EA values in Figure 6 apply for typical airport/airbase situations. Variability about the mean values is high with standard deviation typically 6 — 12 dB. **Consequently, the handbook's extrapolated far-field contours represent expected average levels.** Normalized data do not contain the uncertainties introduced by the average EA, since the measurement distance D_o and standard normalization distances (10 meters and 100 meters) are so small that the associated EA values are zero or negligible.

These EA data apply for sound propagating downwind or on still days. Excess attenuation of sound propagating upwind is generally greater than for downwind. Therefore, the handbook far-field contours somewhat overestimate the noise levels for upwind propagation and the associated limiting exposure times reported are conservative. From these normalized and extrapolated SPL spectra we calculated OASPL, OASLA, OASLC, PSIL, PNL/PNLT and limiting exposure times T with and without ear protectors.

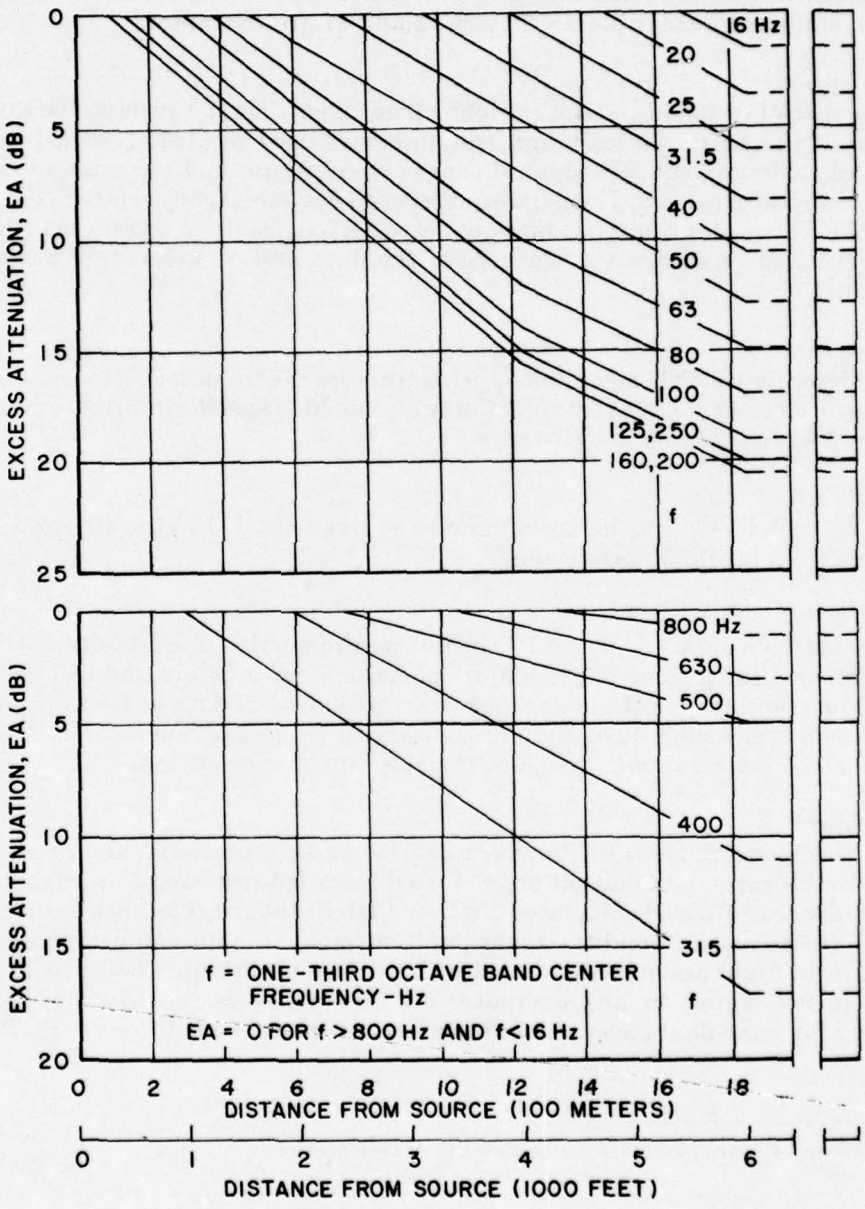

Figure 6. Excess Attenuation[24,7]

FORMAT AND EXAMPLES OF HANDBOOK DATA

GENERAL

In this section each type of format used to present noise data in the handbook is examined. There are only eight basic formats: two for inflight and near-field noise; four for far-field noise; and two for source power and directivity data.

The handbook presents all noise data in the form of computer-generated tables and figures, which have standard header blocks. Tables 12 and 17 are examples:*

Identification

The block located in the upper right corner identifies the specific OMEGA program that produced the page, the test and run numbers used by AMRL to identify the test program and computer run, the date of that computer run, and the page number of that particular computer printout. The page number does not necessarily relate to the handbook's page number. These identification data enable AMRL to locate and track specific results in our data bank and reconstruct the source of the data and all processing parameters and computations.

Table or Figure

The table (or figure) title and number printed across the top describe the measures or type of data presented on that page. This block may also include specific information such as units of measure, frequency band and distance.

Noise Source/Subject

This block identifies the specific noise source (e.g., F-15 aircraft), and the general subject area (e.g., far-field noise levels).

Operation

For far-field data, e.g., Table 17, the information in this block describes the operation of the source, including some of the major operational parameters and test conditions. We usually do not use this operation block for near-field aircraft data or for in-flight data, e.g., Table 12, because one such table often presents data for several operations. The alphabetic designator above each column identifies the relevant test condition.

Meteorology

In this block we print the temperature, barometric pressure, and relative humidity applicable to the noise data on that page. Actual recorded test condition values apply to all far-field measured SPL and calculated PWL and DI. Standard reference values (15 C, 0.760 meter Hg, 70% relative humidity) apply to all normalized data and extrapolated far-field contours. For in-flight and near-field data we leave this block empty because meteorological variables do not figure in any computation. Nevertheless, we usually document the meteorology for near-field measurements as part of the test conditions (e.g., Table 2).

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*Tables 12-19 and Figures 7-18 are all at the end of this section.

IN-FLIGHT AND NEAR-FIELD NOISE

Measured Sound Pressure Level

The handbook presents the measured sound pressure levels in dB (reference 2 x 10^{-5} newton/square meter) for in-flight and near-field noise in terms of overall, octave band and 1/3 octave band levels. Tables 12 and 13 are examples. Each column of data defines the SPL spectrum and OASPL for the particular measurement location and test condition (e.g., 1/A) designated above the column. The earlier section on field measurements discussed the meaning and use of such designators; e.g., see Tables 1 and 2. Sometimes we labeled columns with specific information instead of designators as shown on Table 14 for near-field AGE data.

Those 1/3 octave band SPL values that were corrected for the influence of spurious background/electronic noise are flagged on the table with a symbol (<) and footnoted. No such flags ever appear on octave band SPL nor OASPL values because these measures were calculated from the corrected 1/3 octave band levels. Blanks in the table indicate that either no data were acquired or that those levels were deleted because of spurious noise, as discussed earlier.

Measures of Human Noise Exposure

For each location/condition measured, the handbook also provides six measures of noise in addition to the SPL. These measures, which help assess the effects of such noise on humans, are presented in table form divided into three categories: Hazard/Protection, Communication, and Annoyance. Table 15 is an example.

Under Hazard/Protection, we first list OASLC and OASLA at the ear with no ear protection and the corresponding maximum permissible time T for one (or total) daily exposure to that level. Next, we list OASLA under each of several protectors and the corresponding T values. Letter symbols were sometimes printed in lieu of T values along with corresponding footnotes below those tables on which they appeared. Table 16 summarizes these symbols, footnotes and their meaning.

We list PSIL separately under the Communication category and PNLT and C or just PNL under the Annoyance category.

FAR-FIELD NOISE

Measured Sound Pressure Level

We prepared the far-field measured SPL in much the same format used for near-field data. For example, Table 17 shows 1/3 octave band SPL spectra and overall SPL in dB (reference 2 x 10^{-5} newton/square meter) measured at a fixed distance as a function of angle around an aircraft. This source was rotationally symmetric about its centerline. Similar data on aerospace ground equipment (AGE) or other non-symmetric sources required a two-page presentation, Table 18, covering 36 angles from 0 to 360 degrees. For all far-field handbook data the forward direction of the aircraft or the AGE tow bar direction defined the 0 degree reference azimuth.

Missing data were either not measured or were deleted because of background or electronic noise. We again used the symbol (<) to flag all data corrected for such spurious noise.

Generally, we did not include octave band levels for the far-field measured SPL because the normalized and extrapolated data include such levels for reference meteorological conditions.

Normalized Noise Levels

Figure 7 illustrates how the handbook presents the measured data normalized to a reference distance and standard meteorology. Reference distances are generally 100 meters for aircraft and 10 meters for AGE.

Three of the small graphs give the normalized SPL as a function of angle around the source for nine standard octave bands with center frequencies from 31.5 to 8000 Hz. Symbol legends are above each graph. We draw one contour line on each of these three graphs (always the 63, 500, and 4000 Hz contours) to help display the source's directional characteristics yet avoid the clutter resulting if all nine contours were shown.

The fourth graph in the lower right corner presents OASPL, OASLA, PSIL and PNLT as a function of angle. All four measures use a common abscissa scale.

Note that the resolutions are 1dB per scale point on the absicissas and 10 degrees per scale point on the ordinates. Thus, we can directly read any level to the nearest integer value for any 10-degree increment without interpolating.

For non-symmetric sources, the handbook presents two such outputs placed on facing pages to cover 0 to 360 degrees.

This presentation summarizes the far-field noise characteristics of a source in a standard, compact form especially useful for comparing different sources of the same class; i.e., aircraft to aircraft or AGE-to-AGE. We recommend its use for this purpose.

Acoustic Power Level and Directivity Index

The format for acoustic power level PWL, Figure 8, is tabular and graphical and gives the overall, octave band and 1/3 octave band PWL in dBp (reference 10^{-12} watt). In a few rare instances, the 1/3 octave band PWL may not be available.

Graphical resolutions are 1 dB per scale point on the abscissa and 1/3 octave frequency increments per scale point on the ordinate. Thus, the frequency scale is logarithmic. A straight-segment line shows the spectral distribution for the two frequency bandwidths. Levels may be read to the nearest integer value for each band or overall without interpolation. The PWL values tabbed on the right side provide the same data but rounded to the nearest 0.1 dB.

Requirements for resolution and dynamic range, coupled with practical limits on computer outputs, dictated that these PWL functions be graphically depicted in this somewhat unorthodox, rotated fashion: i.e., with frequency on the ordinate instead of the abscissa.

The handbook tabulates the directivity index, DI, for the overall, octave, and 1/3 octave bands. Table 19 is an example.

Missing PWL or DI points correspond to SPL points missing. Either we did not acquire or else deleted such data points because of background/electronic noise.

These data represent the acoustic power emitted by the source and its directivity under the meteorological conditions at the time of test. We present such data only for aircraft or other sources with rotationally symmetric sound fields.

Noise Level Contours

The handbook presents level contours that enable the reader to easily read levels at any reasonable far-field distance and angle from a source. Figures 9 through 14 are examples for the six measures typically presented: OASPL, OASLC, OASLA, PSIL, PNLT, and octave band SPL. Only one octave band SPL contour set is shown here as an example, but the handbook usually includes contour sets for nine octave bands with center frequencies from 31.5 to 8000 Hz.

The OMEGA 1 program derived these contours by first applying the extrapolation procedures described earlier to calculate 1/3 octave band SPL spectra at seven discrete distances for each angle. Table 20 lists the distance ranges of contour sets typically used for different types of sources. Next, OMEGA 1 calculated the six measures for each distance in that set and then applied an interpolation and smoothing algorithm,[25] which fitted a curve to each of the seven-point functions. From such curves the program interpolated the distance corresponding to specific levels for each angle. We did not allow the program to extrapolate below certain levels: 35 dB for band SPL and PSIL; 45 dB for OASPL, OASLC and OASLA; and 60 dB for PNLT and PNL. By this method OMEGA 1 defined the points necessary to describe the equal level contours for each measure.

On each contour set the distance scale is logarithmic with 40 scale points per decade of frequency. The angle scale on the ordinate is linear with data points typically spaced at 10-degree intervals. A legend on the right of each contour set identifies each point symbol.

These points define the levels every 5 dB (or 5 dBA, 5 PNdB, etc.). We drew and labeled contours for levels every 10 dB. All contour sets are sized to allow direct overlays of standard, semi-log tracing paper which facilitates comparison between sources and the construction of composite and special purpose graphs. Any semi-log paper with 3 1/3 inches per decade on the log scale will work (e.g., K&E tracing paper 46 5733). The single exception is Volume 3 of the handbook on the A-1 generator set, the prototype volume, in which the contour sets were accidentally printed undersize.

A two-page spread, such as Figure 15, presents contours from 0 to 360 degrees for AGE or other non-symmetric sources.

We placed all contours with distance on the abscissa to achieve the best resolution and distance range consistent with the practical limits of the computer printout. We also investigated the use of computer controlled plotters to produce these contours, but selected the method used for reasons of efficiency and cost.

The handbook's extrapolated far-field contours represent expected average levels, assuming meteorological conditions that, on the average, approximate the standard reference conditions of 15 C temperature, 0.760 meter Hg barometric pressure, and 70% relative humidity. Volume 2[10] provides information on the need for and methods to correct the handbook's standard contour levels for other meteorological conditions if required. The standard contours apply for many operational problems.

Exposure Time Contours

The noise levels necessary to define the contour sets just discussed also suffice to derive exposure time contours that, for any reasonable far-field distance and angle, give the limiting times for one (or total) exposure per workday to the specific sound levels reported. Refer to the earlier section on noise exposure limits for hearing, which discussed exposure to intermittent and multi-level sound fields.

Figure 16 is an example of a contour set applicable for exposed persons not wearing ear protectors. The OMEGA 1 program calculated these limiting times from the extrapolated OASLA and 1/3 octave band SPL by applying the hearing and whole body standards already discussed.

The scales of Figure 16 are identical to those used for the noise level contours. A legend on the figure identifies the time value of each point symbol. These points define the time contours for ten values ranging from 2.2 minutes to 960 minutes (16 hours) per day. We drew and labeled all 2.2-, 8-, 30-, 120-, and 480-minute contours.

Special letter symbols and footnotes identify any region (i.e., locations) on the contour sets where the noise levels exceed permissible limits. These symbols, their meaning, and corresponding footnotes are listed on Table 16. Regions marked with PP are not distinguisible from those marked with P, which is of little consequence. Far-field levels reported in the handbook rarely exceed whole body limits; such a circumstance would cause an N region to be printed on the time contour figure.

The handbook also includes similar exposure time contours for exposed persons wearing those selected ear protectors identified on Table 11. Figure 17 is an example of such contours. In some instances when the source is relatively quiet, some or all of the protectors may sufficiently protect the wearer that permissible exposure times are 960 minutes (16 hours) per workday. A single computer printout summarizes these results as illustrated by Figure 18.

Applicability For Other Operating Conditions

The handbook's far-field noise data on aircraft apply for the particular operating conditions measured. These include runups with single engine, all engines, single engines with others at idle, in-board engines, and out-board engines. Engine settings ranged from idle to maximum takeoff power.

You can use the handbook's far-field data measured for n_1 number of engines to estimate levels for n_2 number of engines at the same power setting by adding a correction C_n to the handbook data

$$C_n = 10 \log \frac{n_2}{n_1} \qquad \text{dB}$$

For example, if the handbook gives data for a particular 4-engine runup and you want single-engine data for the same aircraft and power setting, algebraically add –6 dB (i.e., 10 log 1/4) to handbook SPL, OASLA, OASLC, PSIL, PNLT and PWL values. **You cannot apply this method to near-field data!**

You may also desire to estimate noise levels for engine power settings intermediate between those reported in the handbook. The procedure is simple: From the handbook's noise contour sets determine the noise levels or exposure times (SPL, OASLA, T, etc.) at the angle and distance of interest. Do so for the engine power settings (EPR, RPM, etc.) that bracket the value of interest. Then, interpolate linearly, i.e., plot noise level versus power setting parameter (e.g., RPM); draw a straight line between individual handbook data points; and read off the noise level at the intermediate power value of interest. **We do not recommend extrapolation beyond the range of the power settings reported in the handbook. Also, do not interpolate between a non-afterburner level and an afterburner level!**

In a few cases with multi-engine aircraft, a single engine was run and measured while the other aircraft engines were left at idle. The contribution of noise in the far-field from the other engine(s) at idle did not significantly affect data measured on the engine run at higher power.

TABLE: 12 MEASURED SOUND PRESSURE LEVEL (DB) 1/3 OCTAVE BAND

IDENTIFICATION:
OMEGA 3.2
TEST 74-101-001
RUN 01
12 DEC 74
PAGE F1

NOISE SOURCE/SUBJECT:
KC-135A AIRCRAFT
INFLIGHT NOISE LEVELS

OPERATION:

FREQ (HZ)	LOCATION/CONDITION 1/D	1/N	1/P	2/C	2/H	2/I	2/L	2/M	2/N	2/P	2/S	2/T	3/M
25	72	73	72	74	72	71	76	76	69	73	93	77	75
31.5	75	74	74	75	71	70	75	74	72	75	92	78	71
40	75	73	73	71	71	68	73	74	71	74	89	75	70
50	72	73	72	71	69	65	72	73	69	72	84	74	69
63	68	71	81	72	73	69	74	76	70	76	82	74	71
80	67	75	76	71	72	69	72	73	68	73	74	77	74
100	74	75	73	75	75	73	76	78	74	72	77	77	78
125	69	72	76	72	76	69	74	75	69	75	76	78	76
160	61	67	72	70	73	67	72	71	68	72	74	76	74
200	63	66	66	71	70	68	70	72	65	70	75	78	71
250	66	64	66	74	69	66	71	71	66	70	79	73	68
315	72	68	69	76	70	69	72	74	69	69	80	77	71
400	74	69	73	77	73	73	78	78	72	75	78	81	73
500	69	70	77	74	75	74	79	79	73	76	79	78	74
630	70	76	77	73	78	78	81	81	75	79	76	74	76
800	73	86	79	72	79	79	83	83	82	80	75	70	76
1000	80	78	77	76	78	78	83	83	77	79	78	71	76
1250	82	83	79	78	78	78	82	83	77	80	76	70	76
1600	83	80	82	74	80	80	84	84	79	82	72	69	78
2000	83	78	86	73	81	82	86	85	79	88	72	73	80
2500	79	75	79	69	78	79	84	84	78	80	72	80	77
3150	80	76	78	71	77	79	88	87	84	80	68	67	80
4000	78	70	74	67	72	75	79	78	72	78	69	69	79
5000	76	67	71	65	68	70	75	75	68	74	64	76	74
6300	74	65	69	64	66	68	74	73	69	70	62	70	74
8000	70	64	67	62	65	67	73	72	66	68	60	71	71
10000	70	64	68	63	65	69	74	73	66	71	63	65	73
OVERALL	91	91	91	87	89	89	94	94	90	92	97	90	90

LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: 12 MEASURED SOUND PRESSURE LEVEL (DB) OCTAVE BAND

IDENTIFICATION: OMEGA 3.2 TEST 74-101-001 RUN 01 12 DEC 74 PAGE J1

NOISE SOURCE/SUBJECT: KC-135A AIRCRAFT INFLIGHT NOISE LEVELS

OPERATION:

FREQ (HZ)	LOCATION/CONDITION 1/D	1/N	1/P	2/C	2/H	2/I	2/L	2/M	2/N	2/P	2/S	2/T	3/M
31.5	78	78	78	78	76	74	79	79	75	79	96	81	77
63	74	78	82	76	76	73	77	79	74	79	86	80	77
125	75	77	79	77	79	75	79	80	76	78	80	82	81
250	73	71	72	80	74	72	75	77	71	74	83	81	75
500	76	77	81	80	80	80	84	84	78	82	83	83	79
1000	84	88	83	80	83	83	87	87	84	84	81	75	81
2000	86	83	88	77	84	85	89	89	83	90	77	81	83
4000	83	77	80	73	78	81	89	87	84	83	72	77	83
8000	76	69	73	68	70	73	78	77	72	74	67	74	78
OVERALL	91	91	91	87	89	89	94	94	90	92	97	90	90

TABLE: 13 MEASURED SOUND PRESSURE LEVEL (DB) 1/3 OCTAVE BAND

IDENTIFICATION:
OMEGA 3.2
TEST 73-067-011
RUN 02
02 DEC 74
PAGE F1

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
GROUND CREW
NEAR FIELD NOISE LEVELS

OPERATION:

LOCATION/CONDITION

FREQ (HZ)	1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8	9/8	10/8
25	72	79	86	88	86	84	92	91	88	86
31.5	74	81	89	90	90	86	90	93	92	87
40	75	83	92	93	91	87	88	89	87	83
50	72	80	89	89	90	85	89	88	84	80
63	74<	81	90	91	93	87	92	90	83	80
80	71<	78	86	88	91	85	91	88	82	79
100	75	80	90	93	91	86	87	88	83	83
125	76	80	90	92	89	85	90	97	87	83
160	76	80	91	93	91	87	94	101	89	86
200	77	78	92	92	90	84	91	93	85	83
250	77	79	93	93	91	85	90	92	85	82
315	77	79	93	94	90	86	92	93	88	83
400	81	86	95	96	98	93	102	100	94	88
500	81	80	94	95	90	86	92	92	86	88
630	81	80	94	95	90	86	91	92	87	88
800	82	81	96	96	95	89	96	95	90	87
1000	84	83	98	97	91	87	93	93	87	86
1250	91	87	105	103	96	91	95	95	89	84
1600	94	90	109	107	98	93	97	96	92	85
2000	93	91	107	106	96	90	94	93	89	84
2500	111	109	127	125	113	107	109	107	103	94
3150	106	106	122	122	109	103	105	104	99	91
4000	111	106	125	123	108	104	106	106	100	97
5000	107	105	122	121	106	102	103	102	98	95
6300	106	103	121	120	103	98	99	98	93	90
8000	106	104	122	120	103	98	100	100	94	93
10000	104	101	120	118	100	95	97	97	92	97
OVERALL	116	114	132	130	117	111	114	113	108	104

< LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: 13 MEASURED SOUND PRESSURE LEVEL (DB) OCTAVE BAND

IDENTIFICATION:
OMEGA 3.2
TEST 73-067-011
RUN 02
02 DEC 74
PAGE J1

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
GROUND CREW
NEAR FIELD NOISE LEVELS

OPERATION:

LOCATION/CONDITION

FREQ (HZ)	1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8	9/8	10/8
31.5	79	86	94	95	94	91	95	96	94	90
63	77	85	93	94	96	90	96	93	88	84
125	80	85	95	97	95	91	96	102	92	89
250	82	83	98	98	95	90	96	97	91	87
500	86	87	99	100	99	94	103	101	95	93
1000	92	89	106	105	99	94	100	99	94	90
2000	111	109	127	125	113	107	109	107	103	95
4000	113	110	128	127	113	108	109	109	104	100
8000	110	107	126	124	107	102	103	103	98	99
OVERALL	116	114	132	130	117	111	114	113	108	104

TABLE: 14 MEASURED SOUND PRESSURE LEVEL (DB) 1/3 OCTAVE BAND

IDENTIFICATION:
OMEGA 3.2
TEST T1-020-220
RUN 02
14 AUG 74
PAGE F1

NOISE SOURCE/SUBJECT:
MA-3 AIR CONDITIONER
NEAR FIELD NOISE LEVELS

OPERATION:
1750 RPM

FREQ (HZ)	DISTANCE (M)-> / ANGLE (DEG)-->	4 260	4 280	4 300	4 320	4 340	2 0	2 20	2 40	2 60	2 80	2 100	2 120	2 140
25						81	72<	73<	73<	70<	70<	69<	71<	68<
31.5		73<	74<	76	79	81	89	90	87	87	86	83	82	81
40		70<	68<	70<	70<	76	77	78	76	74	74	74	73<	73<
50		85	84	85	85	85	86	85	86	81	83	85	83	83
63		96	93	93	91	90	101	104	107	101	93	92	94	94
80		84	84	85	85	87	98	101	102	100	96	90	85	84
100		86	82	86	90	90	100	98	98	95	96	98	99	95
125		96	93	99	103	103	113	109	108	107	110	111	111	108
160		83	82	83	85	87	95	95	96	95	95	95	92	93
200		92	90	91	93	95	102	103	104	101	96	95	95	92
250		91	87	86	87	86	93	96	94	94	101	99	98	93
315		79	78	81	78	83	91	93	92	89	86	90	90	83
400		78	76	81	78	83	86	87	86	87	85	91	92	83
500		75	77	77	81	78	87	86	86	84	82	83	84	81
630		79	83	86	89	86	91	89	87	85	86	86	87	84
800		79	82	84	88	85	94	91	89	87	85	85	91	85
1000		76	77	78	78	78	85	87	85	85	83	85	88	84
1250		74	71	73	74	76	84	85	83	82	81	82	85	77
1600		73	71	73	73	76	86	86	84	81	80	81	85	78
2000		71	69	70	73	75	85	85	83	82	81	80	81	75
2500		69	68	71	72	75	85	85	85	80	78	77	78	75
3150		69	67	68	71	75	83	87	89	81	78	77	78	74
4000		69	67	67	71	74	83	86	89	81	79	77	77	73
5000		68	65	66	70	74	83	89	91	83	77	76	76	72
6300		67	63	65	68	72	81	87	90	82	75	74	74	70
8000		67	62	63	67	70	81	86	90	82	75	72	73	69
10000		64	59	60	64	66	78	85	89	80	73	70	70	66
OVERALL		101	99	101	104	105	114	112	112	110	111	112	112	109

< LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: MEASURES OF HUMAN NOISE EXPOSURE

15

IDENTIFICATION:
OMEGA 3.2
TEST 73-067-011
RUN 02
02 DEC 74
PAGE H1

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
GROUND CREW
NEAR FIELD NOISE LEVELS

OPERATION:

	LOCATION/CONDITION									
	1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8	9/8	10/8
HAZARD/PROTECTION										
C-WEIGHTED OVERALL SOUND LEVEL (OASLC IN DBC) AT EAR										
A-WEIGHTED OVERALL SOUND LEVEL (OASLA IN DBA) AT EAR										
MAXIMUM PERMISSIBLE TIME (T IN MINUTES) FOR ONE EXPOSURE PER DAY (AFR 161-35, JULY 73)										
NO PROTECTION										
OASLC	115	113	131	129	116	111	113	112	107	103
OASLA	117	115	132	131	117	112	114	113	108	103
T	P	2.2	P	P	P	3.8	2.7	3.2	8	18
MINIMUM QPL EAR MUFFS										
OASLA*	89	87	104	103	89	84	87	87	81	78
T	202	285	15	18	202	480	285	285	807	960
AMERICAN OPTICAL 1700 EAR MUFFS										
OASLA*	83	81	99	97	83	78	81	81	75	73
T	571	807	36	50	571	960	807	807	960	960
V-51R EAR PLUGS										
OASLA*	86	83	101	99	86	81	84	83	78	75
T	339	571	25	36	339	807	480	571	960	960
AMERICAN OPTICAL 1700 EAR MUFFS PLUS V-51R EAR PLUGS										
OASLA*	73	70	88	87	73	67	70	69	64	62
T	960	960	240	285	960	960	960	960	960	960
H-133 GROUND COMMUNICATION UNIT										
OASLA*	90	88	105	104	91	86	88	86	82	75
T	170	240	13	15	143	339	240	339	679	960
COMMUNICATION										
PREFERRED SPEECH INTERFERENCE LEVEL (PSIL IN DB)										
PSIL	96	95	110	110	104	98	104	103	97	93
ANNOYANCE										
PERCEIVED NOISE LEVEL, TONE CORRECTED (PNLT IN PNDB)										
TONE CORRECTION (C IN DB)										
PNLT	134	131	149	147	135	129	131	130	125	120
C	4	4	4	4	4	3	3	3	3	2

* BASED ON CALCULATED SPL SPECTRUM UNDER PROTECTIVE DEVICE.
P ADDITIONAL EAR PROTECTION REQUIRED.

TABLE 16

SYMBOLS AND FOOTNOTES USED ON HANDBOOK DATA TO IDENTIFY WHEN LEVELS EXCEED HUMAN NOISE EXPOSURE LIMITS

Symbol	*Footnote*	*Used Whenever Noise Levels:*
P	Additional Ear Protection Required	Exceed hearing limits, Fig. 4
PP	Ear Protection Required To Avoid High Frequency, Whole Body Effects	Exceed whole body 85 dB limit for 12,500 — 40,000 Hz, Fig. 5
<	Time Limit Set To Avoid Whole Body Effects	Are such that whole body limits, Fig. 5, determine allowable exposure time.
N	Do Not Expose Personnel. Level Exceeds Limit for Whole Body Effects	Exceed whole body limits, Fig. 5

TABLE: 17

MEASURED SOUND PRESSURE LEVEL (DB)
1/3 OCTAVE BAND
DISTANCE = 75 METERS

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 2

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 13 C
BAR PRESS = .703 M HG
REL HUMID = 26 %

FREQ (HZ)	ANGLE (DEGREES) 0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
25	81	80	80	80	82	82	83	83	84	93	89	90	94	98	102	104	101		
31.5	81	81	80	81	82	82	84	86	87	92	92	92	99	101	104	106	105		
40	83	83	83	83	84	85	88	88	90	91	91	95	99	104	107	108	105		
50	83	83	83	85	86	85	87	88	89	91	93	95	99	106	110	111	105		
63	85	84	86	85	87	88	89	89	90	93	96	99	102	108	113	112	106		
80	88	88	89	90	90	91	90	92	92	95	98	101	105	112	117	114	108		
100	91	91	91	92	91	92	93	94	94	98	100	102	107	113	118	117	111		
125	95	96	96	95	94	96	95	96	97	99	101	105	110	116	120	121	113		
160	97	97	97	96	95	95	96	97	97	101	103	108	114	119	120	120	115		
200	95	97	97	96	96	96	96	96	97	99	103	107	113	120	120	117	112		
250	96	96	97	98	97	96	96	96	97	99	104	107	114	119	121	118	111		
315	97	99	99	97	97	96	96	97	99	99	104	106	114	120	120	120	109		
400	100	99	99	97	97	95	95	97	98	100	103	106	114	117	120	119	107		
500	103	103	102	99	98	94	93	95	97	102	105	109	115	119	119	116	104		
630	102	102	103	101	99	99	95	96	98	101	102	106	110	115	118	115	101		
800	100	100	101	100	98	100	98	97	98	99	99	104	107	114	116	113	99		
1000	97	97	97	96	94	98	98	98	98	99	98	104	105	113	114	111	98		
1250	94	95	96	94	92	95	96	97	98	99	98	104	104	112	113	110	97		
1600	92	95	96	94	93	95	94	96	97	101	99	105	103	113	113	110	96		
2000	90	93	94	94	93	94	94	96	97	100	99	103	102	111	111	108	93		
2500	87	89	90	90	90	92	91	94	95	98	99	102	100	109	110	106	91		
3150	84	86	87	88	88	90	90	92	93	97	96	100	98	108	107	104	88		
4000	84	86	86	88	87	90	89	91	93	98	98	101	99	108	109	105	87		
5000	80	81	81	83	82	85	85	87	88	93	94	97	96	105	105	100	83		
6300	76	77	78	79	79	82	81	84	85	88	90	93	93	102	103	98	80		
8000	72	73	73	75	74	77	77	79	81	86	88	91	92	103	103	98	77		
10000	68	68	69	70	70	72	72	75	76	81	83	87	88	99	99	95	72		
OVERALL	110	110	110	109	108	108	107	108	109	112	114	118	123	129	130	129	121		

LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: 18

MEASURED SOUND PRESSURE LEVEL (DB)
1/3 OCTAVE BAND
DISTANCE = 10 METERS

IDENTIFICATION:
OMEGA 1.4
TEST 71-020-220
RUN 01
10 FEB 75
PAGE 2

NOISE SOURCE/SUBJECT:
MA-3 AIR CONDITIONER
FAR FIELD NOISE LEVELS

OPERATION:
1750 RPM

METEOROLOGY:
TEMP = 30 C
BAR PRESS = .764 M HG
REL HUMID = 63 %

FREQ (HZ)	ANGLE (DEGREES) 0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
25																			
31.5	69<	69<	70<	69<	70<	71<	71<	71<	71<	71<	70<	70<	70<	69<	70<	69<	70<	70<	68<
40	65<	65<	65<	64<	65<	64<	64<	65<	64<	64<	64<	65<	64<	63<	65<	65<	65<	65<	65<
50	78	78	77	77	78	78	79	78	77	78	77	78	78	77	78	77	77	77	77
63	88	87	87	86	84	83	83	82	83	83	84	86	86	86	88	89	90	91	91
80	83	83	84	85	85	86	86	86	85	84	84	83	83	82	81	79	78	77	77
100	85	86	86	86	85	83	80	80	82	85	86	86	86	86	86	84	83	84	86
125	96	97	98	98	97	96	94	95	96	98	99	98	99	98	97	96	96	96	97
160	79	78	77	78	79	79	79	79	80	81	81	81	80	78	79	79	80	81	81
200	70<	73	70<	72<	73	73	72	70<	73	74	76	78	80	80	78	76	77	77	78
250	73	75	74	73	75	76	75	74	77	79	80	79	79	79	78	79	78	79	79
315	71	72	72	72	72	72	71	70	69	69	69	69	69	70	70	69	69	68	68
400	72	71	71	70	71	72	70	70	72	72	71	70	68	69	69	67	69	69	67
500	73	75	73	72	74	72	71	72	71	71	73	71	69	69	70	69	69	68	66
630	75	72	72	75	71	72	71	69	72	70	71	71	73	71	71	68	69	66	66
800	75	74	71	76	73	73	73	68	70	69	69	69	74	71	71	69	69	66	64
1000	67	67	68	71	68	69	69	67	67	69	70	68	72	71	69	68	67	67	66
1250	67	68	68	68	69	68	67	68	69	68	68	71	70	68	67	66	66	63	63
1600	68	69	68	67	67	66	67	67	66	66	65	68	69	67	68	68	66	64	64
2000	66	67	67	66	67	66	65	65	66	67	66	65	68	67	66	65	64	63	64
2500	67	67	67	66	66	65	65	64	65	64	65	65	66	66	65	65	63	63	61
3150	66	65	65	65	65	65	65	64	63	63	63	63	63	64	63	63	62	63	61
4000	65	64	65	64	64	64	65	64	64	62	63	63	63	64	63	62	62	61	61
5000	63	63	63	63	62	63	63	62	62	61	61	62	62	62	61	61	59	60	59
6300	61	61	62	61	61	63	61	60	61	60	60	61	60	60	59	60	59	58	58
8000	61	61	61	60	60	63	61	60	60	60	60	60	59	60	59	59	58	58	58
10000	59	59	59	58	58	60	59	58	58	58	58	59	58	59	57	57	57	56	56
OVERALL	97	98	98	99	98	97	95	96	97	98	99	99	99	99	98	97	97	98	99

< LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE 18: MEASURED SOUND PRESSURE LEVEL (DB)
1/3 OCTAVE BAND
DISTANCE = 10 METERS

IDENTIFICATION:
OMEGA 1.4
TEST 71-020-220
RUN 02
10 FEB 75
PAGE 2

NOISE SOURCE/SUBJECT:
MA-3 AIR CONDITIONER
FAR FIELD NOISE LEVELS

OPERATION:
1750 RPM

METEOROLOGY:
TEMP = 30 C
BAR PRESS = .764 M HG
REL HUMID = 63 %

FREQ (HZ)	ANGLE (DEGREES) 190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
25																	
31.5	69<	68<	68<	67<	65<	65<	66<	66<	67<	65<	69<	70<	69<	68<	68<	69<	70<
40										64<	65<	66<	65<	65<	66<	65<	65<
50	76	76	76	77	77	78	78	77	78	78	80	80	79	80	79	78	78
63	92	92	92	92	92	91	91	91	90	90	91	90	89	88	87	88	88
80	80	80	80	80	80	79	78	78	78	77	77	77	78	78	80	81	82
100	86	86	85	85	86	86	85	84	83	82	81	82	84	85	86	86	86
125	99	98	97	97	96	97	97	96	96	95	93	92	95	96	97	97	97
160	81	80	78	76	75	75	74	75	76	77	77	78	76	76	78	79	79
200	74	74	74	75	75	71<	70<	73	74	73	74	76	75	74	73	74	72
250	74	71	73	73	73	71	72	72	73	75	73	71	72	72	72	74	75
315	67	70	71	70	69	70	69	68	69	66	70	70	70	72	73	73	71
400	69	72	75	74	71	71	71	71	71	72	73	74	74	75	76	76	73
500	66	67	68	70	70	72	72	72	68	73	72	75	74	72	74	78	73
630	69	68	66	70	68	70	71	70	74	76	78	79	79	76	79	73	72
800	70	70	67	70	68	69	69	69	73	72	77	78	78	77	81	75	75
1000	64	65	66	67	66	68	67	67	67	66	67	70	70	69	69	68	67
1250	63	63	66	65	65	67	66	67	66	65	67	68	68	68	68	67	67
1600	61	62	63	62	64	66	65	64	63	64	65	66	67	67	68	68	67
2000	58	60	61	61	64	65	64	63	62	63	64	65	65	67	68	67	68
2500	58	60	61	60	61	62	61	62	61	62	63	65	65	66	66	57	67
3150	58	60	60	58	60	61	60	60	59	60	62	63	65	65	66	66	66
4000	58	59	61	57	60	59	58	59	58	60	61	63	64	64	65	65	66
5000	56	57	60	55	59	58	56	56	56	58	60	62	63	62	63	63	64
6300	54	56	58	52	58	56	55	56	55	57	59	60	62	60	61	62	62
8000	54	55	57	51<	56	55	54	55	55	57	59	59	62	59	60	62	62
10000	51<	53<	54	49<	53<	53<	51<	52<	52<	55	57	56	58	56	57	59	60
OVERALL	100	100	99	98	98	98	98	97	97	96	95	95	96	97	98	98	98

< LEVEL CORRECTED TO REMOVE BACKGROUND/ELECTRONIC NOISE.

TABLE: DIRECTIVITY INDEX (DI)

19

IDENTIFICATION:

OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 4

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 13 C
BAR PRESS = .703 M HG
REL HUMID = 26 %

FREQ (HZ)	ANGLE (DEGREES) 0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	150	170	180
1/3 OCTAVE																			
25	-15	-15	-15	-15	-13	-14	-12	-13	-11	-2	-6	-5	-1	3	6	9	6		
31.5	-17	-17	-18	-17	-16	-16	-14	-12	-11	-6	-6	-6	1	3	6	8	7		
40	-16	-16	-16	-17	-15	-14	-12	-12	-9	-8	-8	-5	-1	5	7	8	5		
50	-19	-19	-19	-17	-16	-17	-15	-14	-13	-11	-9	-7	-3	4	8	9	3		
63	-19	-20	-18	-19	-17	-16	-15	-15	-14	-11	-8	-5	-2	4	9	8	2		
80	-19	-19	-18	-18	-18	-17	-17	-15	-15	-12	-9	-6	-2	5	9	7	0		
100	-18	-18	-18	-17	-18	-17	-16	-15	-15	-11	-9	-7	-2	4	9	8	2		
125	-17	-16	-16	-17	-18	-16	-17	-16	-15	-13	-11	-7	-2	4	8	9	1		
160	-16	-16	-15	-17	-18	-18	-17	-16	-15	-12	-9	-5	1	6	7	7	2		
200	-17	-15	-16	-17	-17	-17	-16	-17	-16	-13	-9	-5	1	8	8	5	-0		
250	-17	-16	-16	-14	-15	-16	-17	-16	-15	-14	-9	-5	1	7	8	5	-2		
315	-16	-14	-14	-16	-16	-17	-17	-16	-14	-14	-9	-7	1	7	7	7	-4		
400	-12	-13	-13	-15	-15	-17	-17	-15	-14	-12	-9	-6	2	5	8	7	-5		
500	-9	-9	-10	-13	-14	-17	-19	-17	-15	-10	-7	-2	3	7	7	4	-8		
630	-7	-7	-6	-8	-10	-10	-14	-14	-11	-8	-8	-4	1	6	8	6	-8		
800	-7	-7	-7	-7	-10	-7	-10	-10	-10	-9	-9	-3	-1	6	8	6	-9		
1000	-9	-9	-9	-10	-12	-8	-8	-8	-8	-8	-8	-2	-2	7	8	5	-9		
1250	-11	-10	-9	-11	-13	-10	-9	-8	-7	-6	-7	-1	-1	7	8	5	-8		
1600	-13	-10	-10	-12	-13	-11	-11	-9	-8	-5	-6	-1	-2	8	7	4	-10		
2000	-13	-11	-10	-10	-11	-9	-9	-8	-6	-4	-5	-1	-1	7	7	4	-10		
2500	-15	-13	-13	-12	-12	-10	-11	-9	-7	-4	-4	0	-2	7	7	4	-11		
3150	-16	-14	-14	-12	-12	-10	-11	-8	-8	-3	-4	-0	-2	8	7	4	-13		
4000	-17	-15	-15	-13	-14	-12	-12	-10	-8	-4	-3	0	-2	7	7	4	-14		
5000	-18	-17	-16	-14	-15	-12	-13	-10	-9	-4	-3	-1	-1	8	7	3	-14		
6300	-18	-18	-17	-16	-16	-13	-14	-11	-9	-6	-4	-2	-2	7	8	3	-15		
8000	-23	-22	-22	-20	-21	-18	-18	-16	-14	-9	-7	-4	-3	8	8	3	-18		
10000	-23	-23	-23	-22	-22	-19	-20	-17	-15	-11	-8	-5	-3	8	8	4	-19		
OCTAVE																			
31.5	-16	-16	-17	-17	-15	-15	-12	-12	-10	-6	-7	-5	-0	4	7	8	6		
63	-19	-19	-18	-18	-17	-17	-16	-15	-14	-12	-9	-6	-2	5	9	7	1		
125	-16	-17	-16	-17	-18	-17	-17	-16	-15	-12	-10	-6	-0	5	8	8	2		
250	-17	-15	-15	-16	-16	-17	-17	-16	-15	-14	-9	-6	1	7	8	6	-2		
500	-9	-9	-9	-12	-13	-15	-17	-15	-14	-10	-8	-4	2	6	8	6	-7		
1000	-9	-8	-8	-9	-11	-8	-9	-9	-8	-8	-8	-2	-1	7	8	5	-9		
2000	-14	-11	-10	-11	-12	-10	-11	-9	-7	-4	-5	-1	-2	7	7	4	-10		
4000	-17	-15	-15	-13	-14	-11	-12	-9	-8	-4	-3	-0	-2	7	7	4	-14		
8000	-20	-20	-19	-18	-18	-15	-16	-13	-12	-8	-6	-3	-2	8	8	4	-17		
OVERALL	-13	-12	-12	-14	-15	-14	-15	-14	-13	-10	-8	-4	1	6	8	6	-1		

TABLE 20

DISTANCE RANGES OF CONTOUR SETS USED IN HANDBOOK TO DESCRIBE FAR-FIELD NOISE

Distance Range (Meters)*		*Typical Application*
5 — 800	Small/Medium	Aerospace Ground Equipment (AGE)
10 — 1600	Large	
20 — 3200	Very Large AGE/Very Small Aircraft	
50 — 8000	Single Engine	Aircraft
75 — 8000	Multi-Engine	
150 — 8000	Very Large Sources	

*Data on contour sets do not necessarily extend to these maximum distances but may be cut off upon reaching minimum values specified in the text.

FIGURE 7 NORMALIZED FARFIELD NOISE LEVELS

DISTANCE = 100 METERS

NOISE SOURCE/SUBJECT:

F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:

MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:

TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

IDENTIFICATION:

OMEGA 1.4
TEST 75-002-029
RUN 03

07 MAY 75

PAGE 6

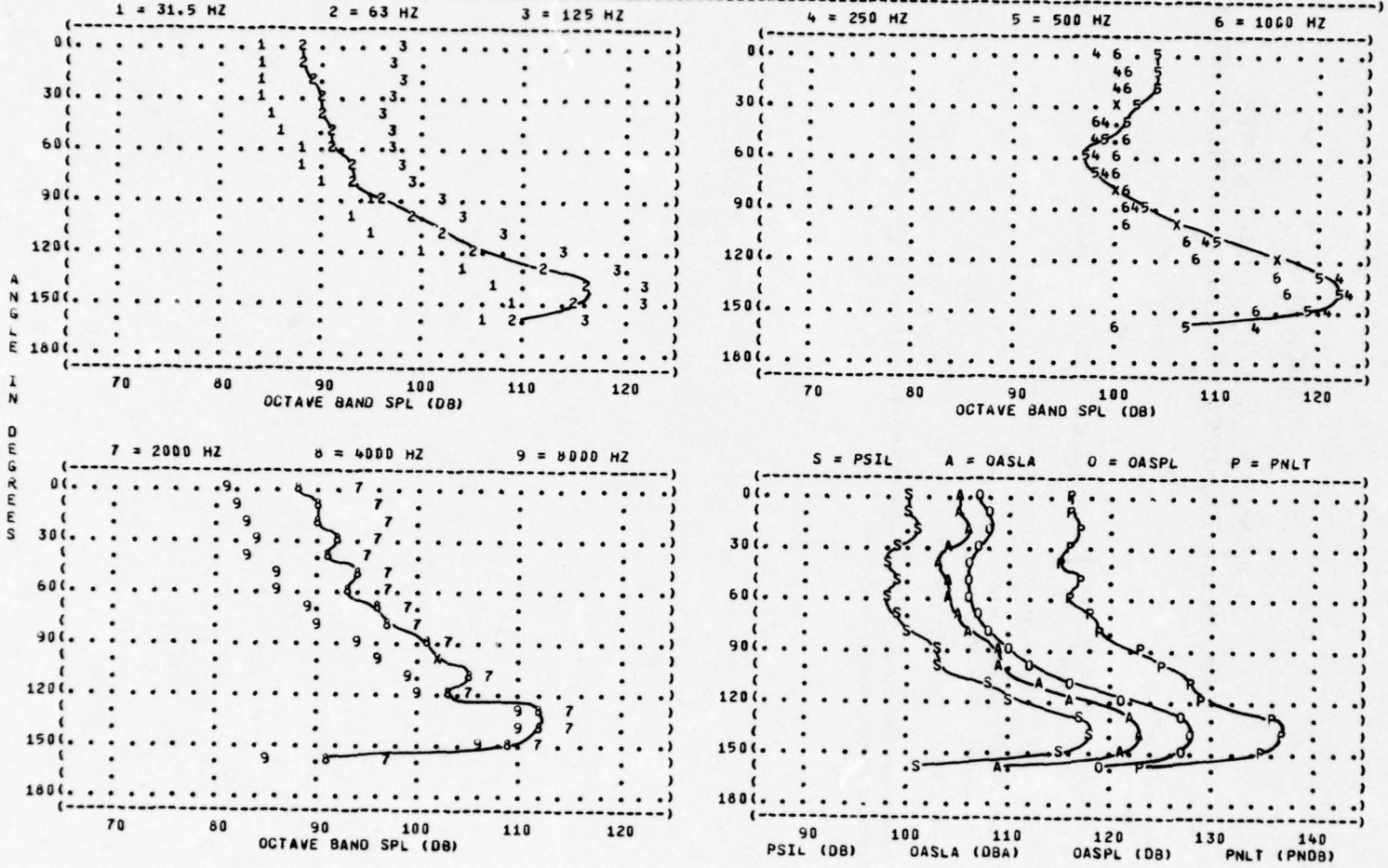


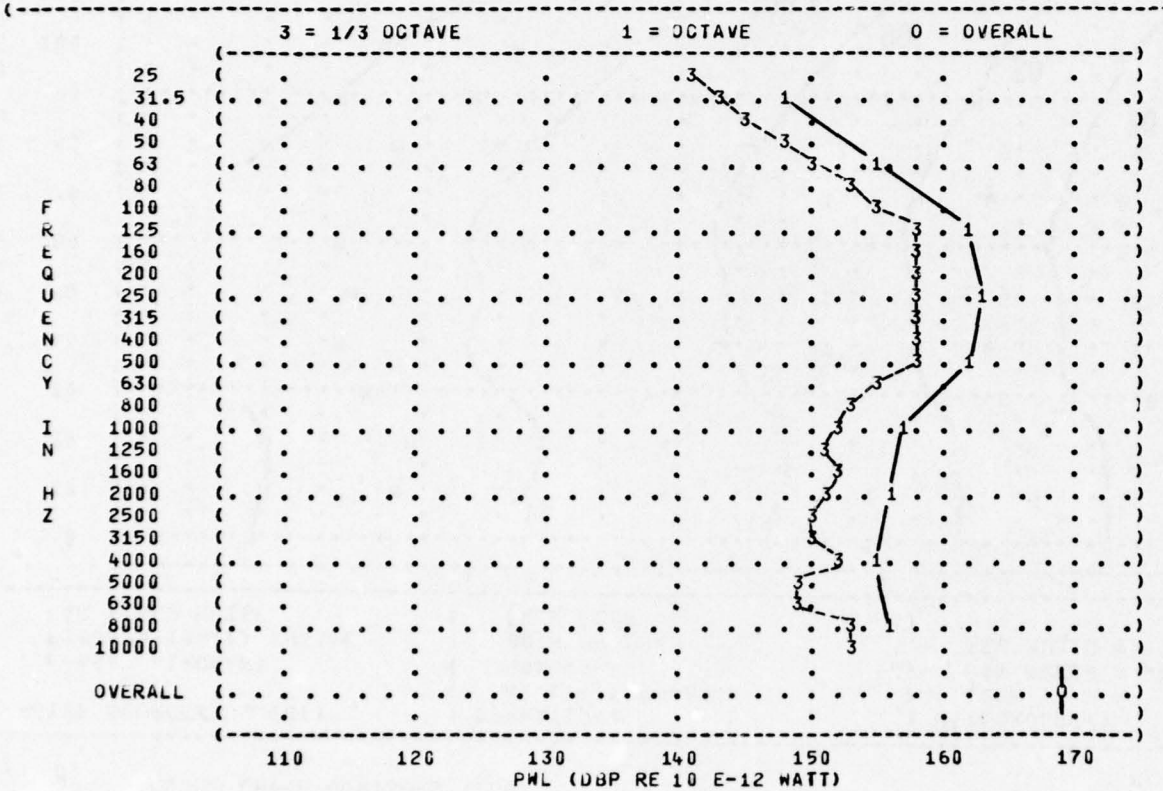
FIGURE: 8 ACOUSTIC POWER LEVEL (PWL)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 3

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 13 C
BAR PRESS = .703 M HG
REL HUMID = 26 %



1/3 OCTAVE	PWL OCTAVE
140.7	
143.4	148.2
145.1	
147.5	
149.6	155.3
152.9	
154.6	
157.6	161.9
158.4	
158.2	
158.3	163.1
158.5	
157.5	
157.5	161.6
155.2	
153.4	
152.4	157.3
151.5	
152.5	
151.0	156.2
150.4	
149.6	
152.0	155.3
149.3	
148.9	
152.5	156.4
152.6	
	168.6

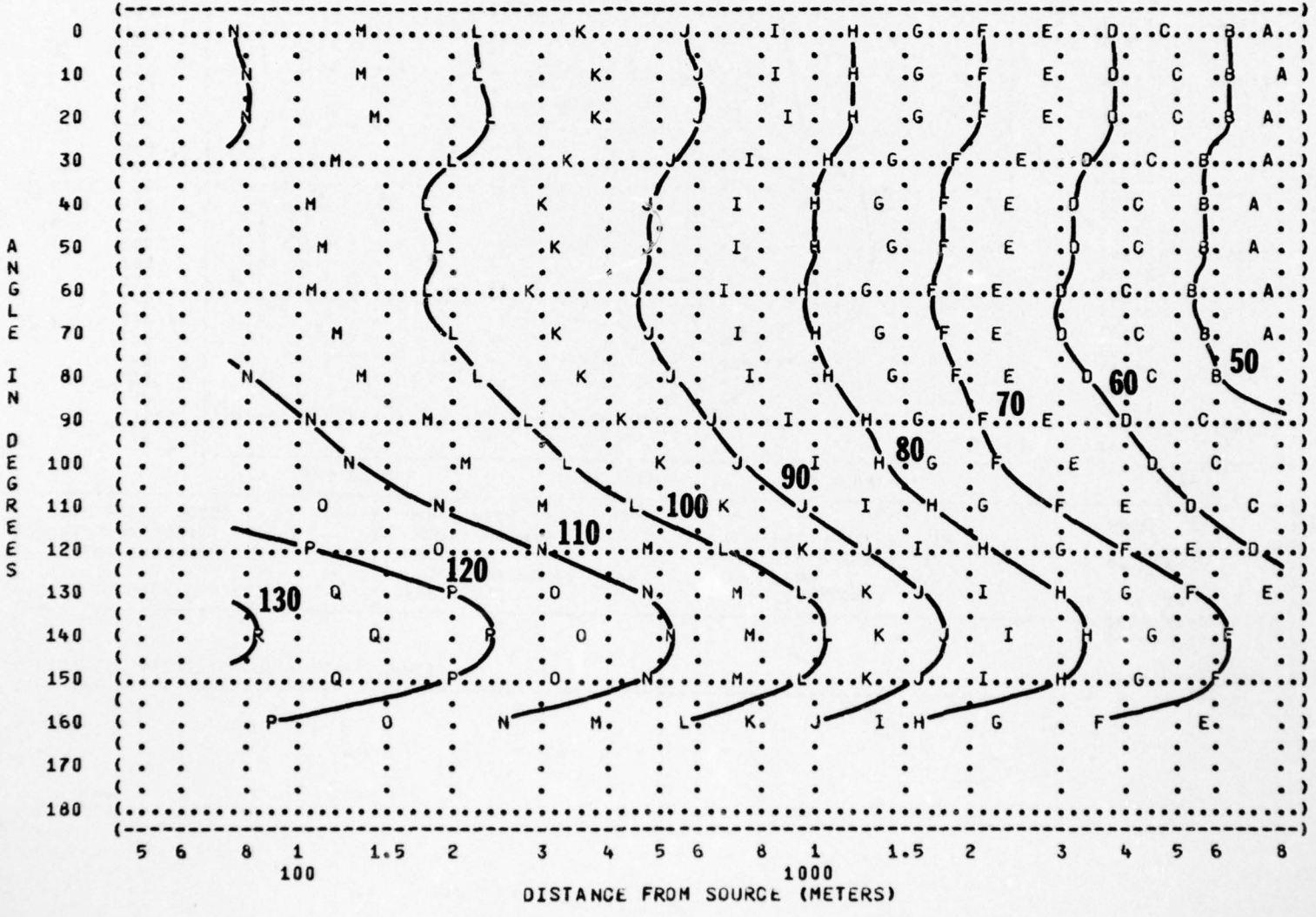
FIGURE 9: OVERALL SOUND PRESSURE LEVEL (OASPL) EQUAL LEVEL CONTOURS (DB)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 13

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DB
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105
N	110
O	115
P	120
Q	125
R	130

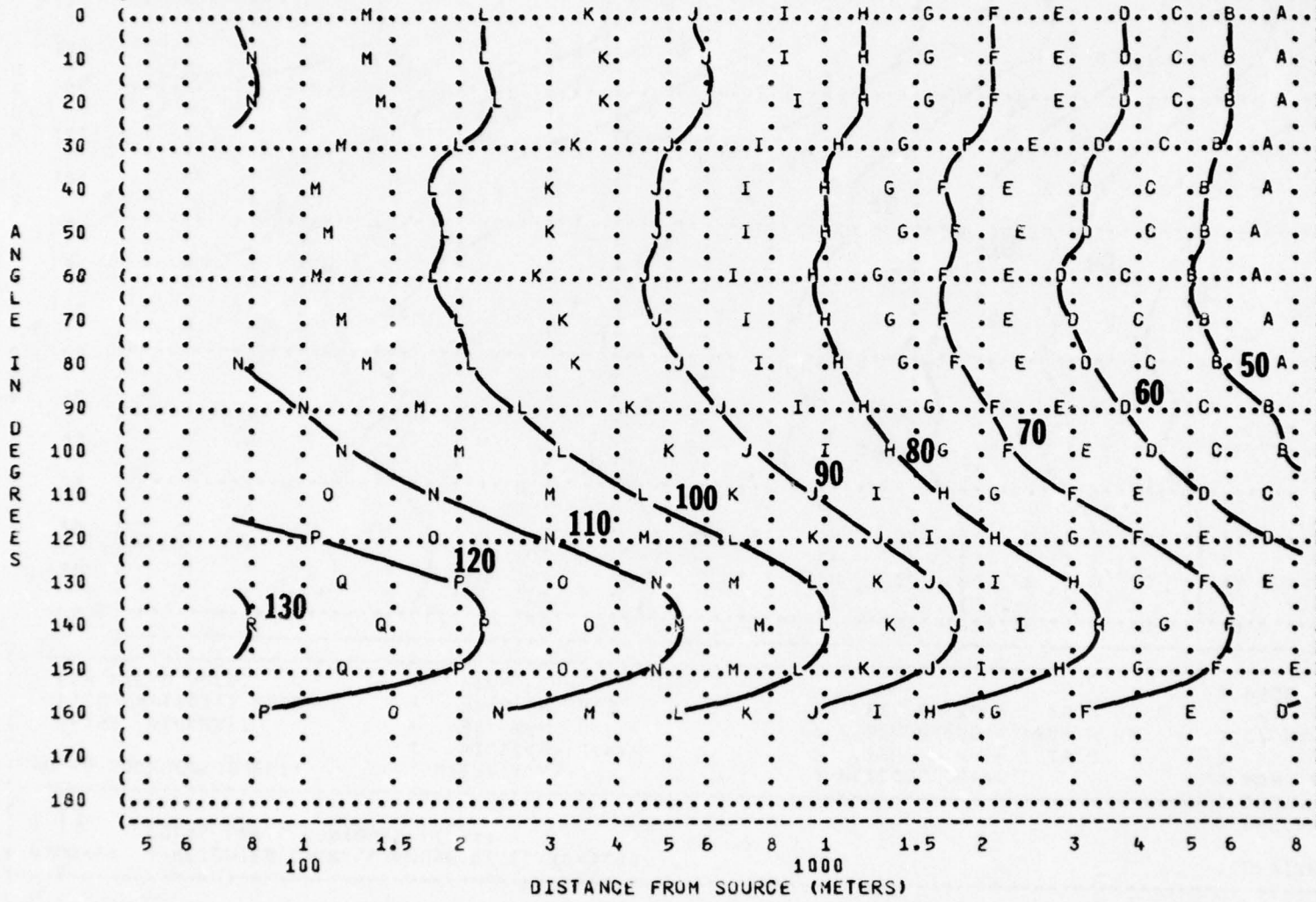
FIGURE: 10 C-WEIGHTED OVERALL SOUND LEVEL (OASLC) EQUAL LEVEL CONTOURS (DBC)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 14

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBC
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105
N	110
O	115
P	120
Q	125
R	130

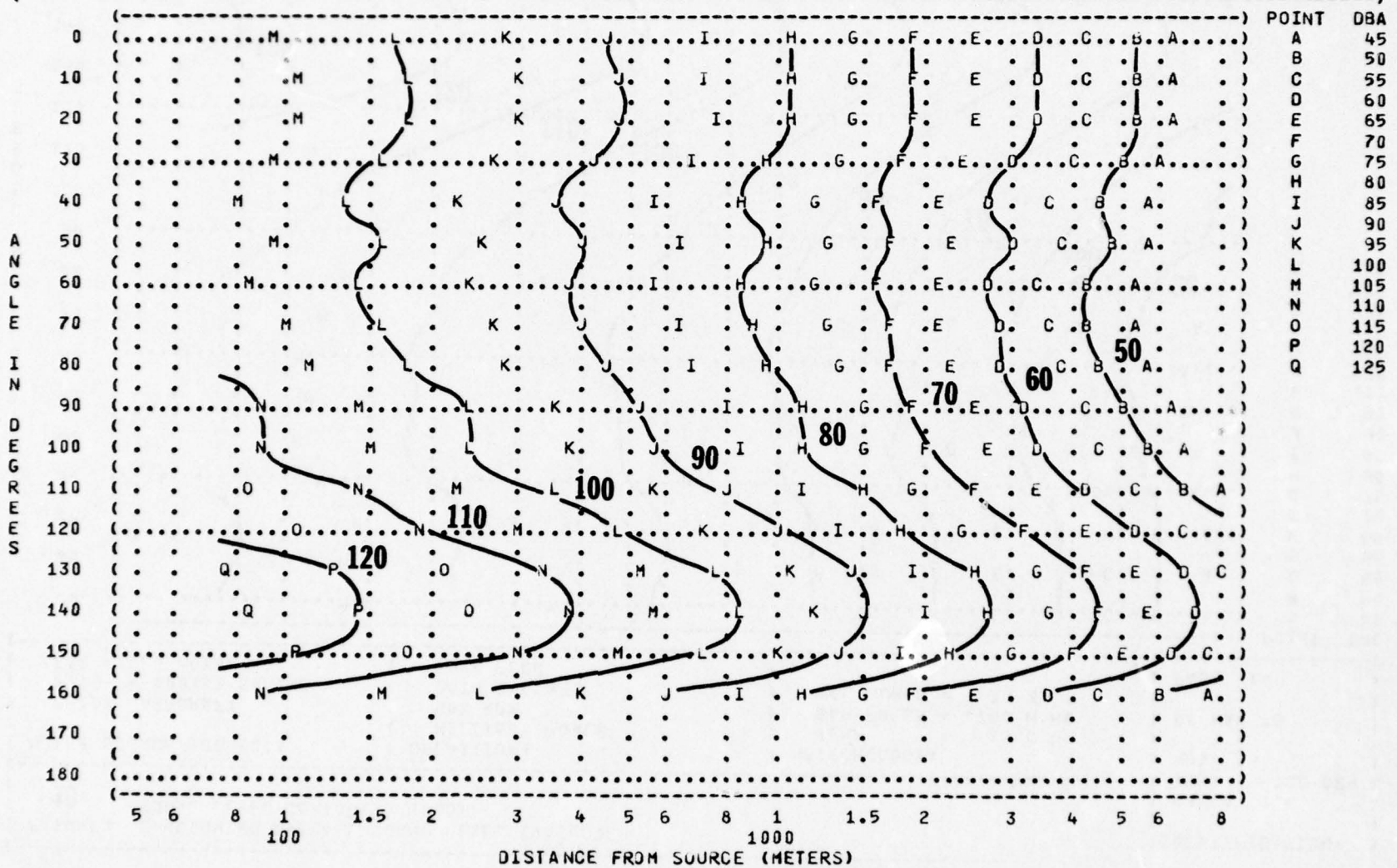
FIGURE: 11 A-WEIGHTED OVERALL SOUND LEVEL (OASLA) EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 15

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105
N	110
O	115
P	120
Q	125

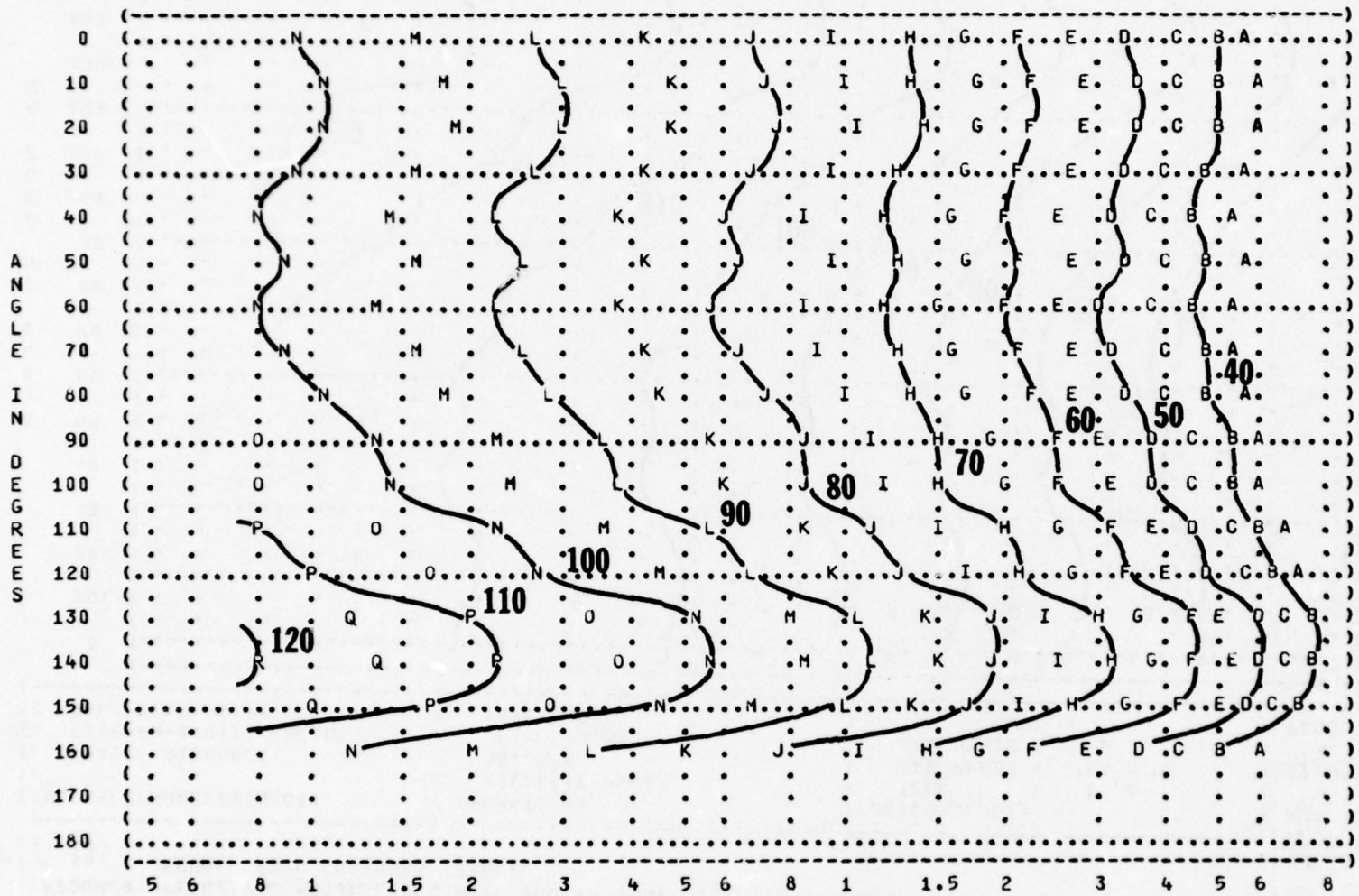
FIGURE: 12 PREFERRED SPEECH INTERFERENCE LEVEL (PSIL) EQUAL LEVEL CONTOURS (DB)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 17

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DB
A	35
B	40
C	45
D	50
E	55
F	60
G	65
H	70
I	75
J	80
K	85
L	90
M	95
N	100
O	105
P	110
Q	115
R	120

FIGURE 13 PERCEIVED NOISE LEVEL WITH SMOOTH TONE CORRECTION (PNLT)
EQUAL LEVEL CONTOURS (PNDB)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 16

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

POINT	PNDB
A	60
B	65
C	70
D	75
E	80
F	85
G	90
H	95
I	100
J	105
K	110
L	115
M	120
N	125
O	130
P	135

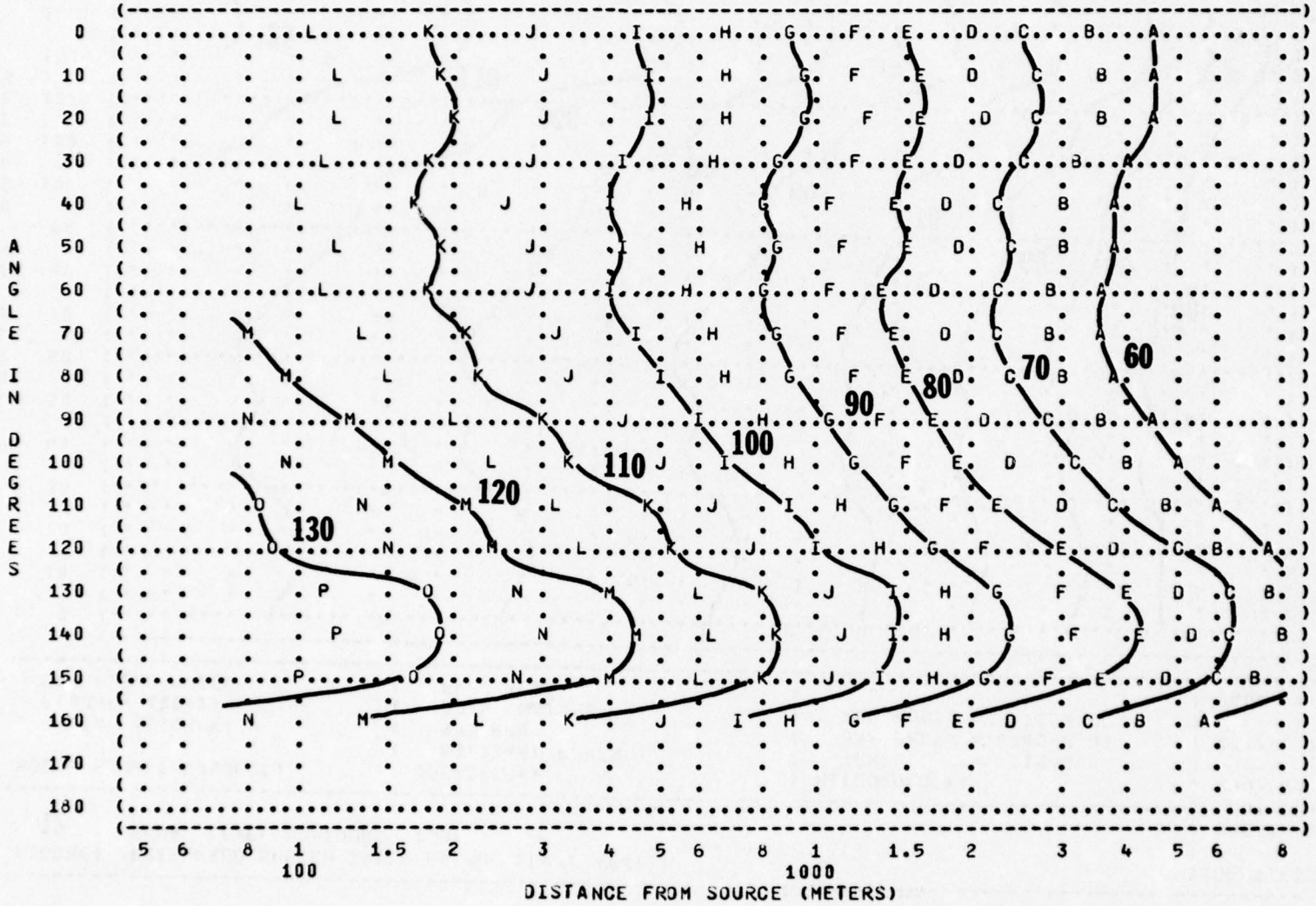


FIGURE: 14

SOUND PRESSURE LEVEL (SPL)
EQUAL LEVEL CONTOURS (DB)
250 HZ OCTAVE BAND

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 21

POINT	DB
A	35
B	40
C	45
D	50
E	55
F	60
G	65
H	70
I	75
J	80
K	85
L	90
M	95
N	100
O	105
P	110
Q	115
R	120
S	125

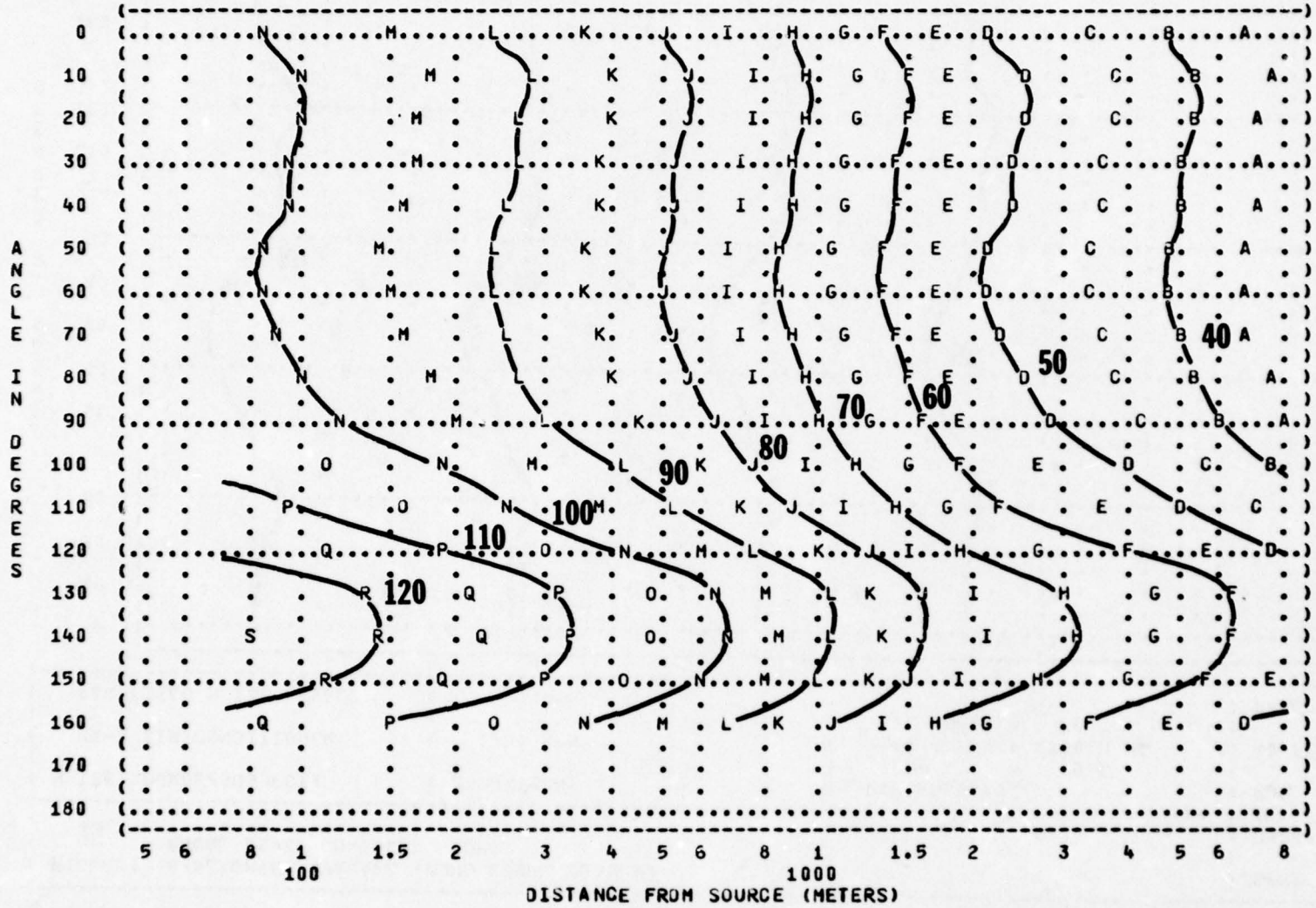


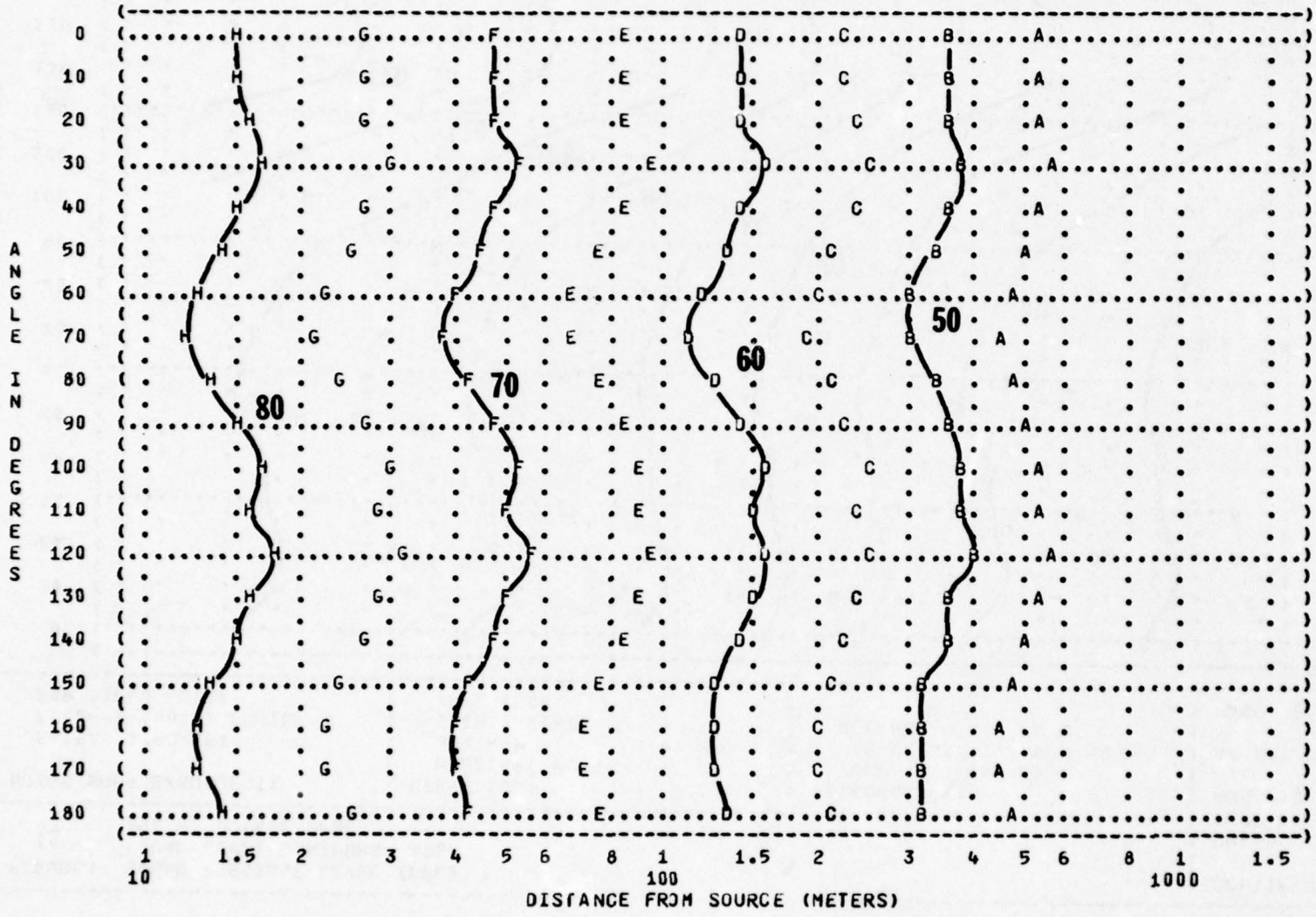
FIGURE: 15 A-WEIGHTED OVERALL SOUND LEVEL (OASLA) EQUAL LEVEL CONTOURS (DBA)

NOISE SOURCE/SUBJECT:
MA-3 AIR CONDITIONER
FAR FIELD NOISE LEVELS

OPERATION:
1750 RPM

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

IDENTIFICATION:
OMEGA 1.4
TEST 71-020-220
RUN 01
10 FEB 75
PAGE 13



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80

FIGURE 15: A-WEIGHTED OVERALL SOUND LEVEL (OASLA) EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 71-020-220
RUN 02
10 FEB 75
PAGE 13

NOISE SOURCE/SUBJECT:
MA-3 AIR CONDITIONER
FAR FIELD NOISE LEVELS

OPERATION:
1750 RPM

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

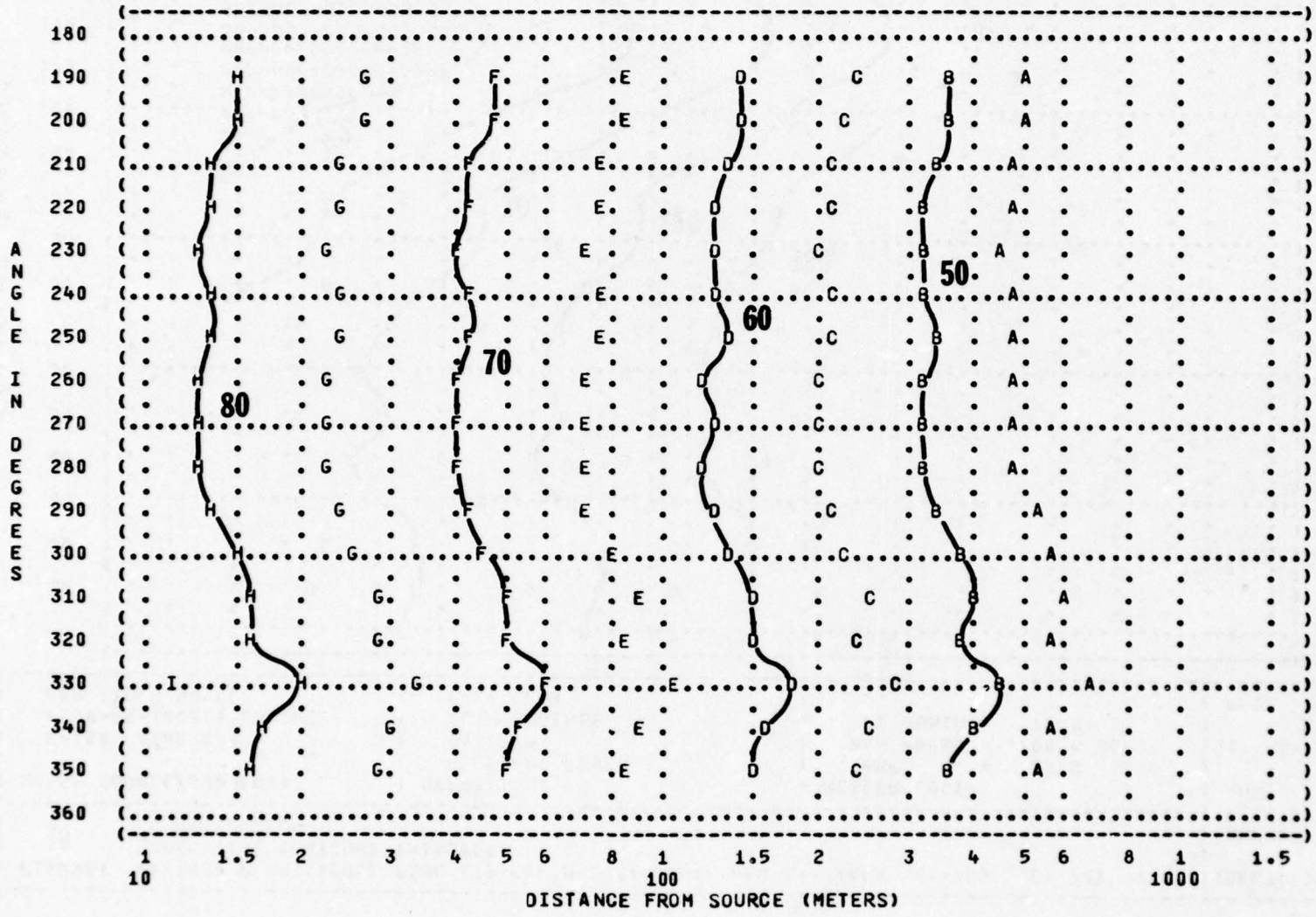


FIGURE: 16 MAXIMUM PERMISSIBLE TIME (T) FOR ONE EXPOSURE PER DAY (AFR 161-35, JULY 73)
EQUAL TIME CONTOURS (MINUTES)
NO PROTECTION

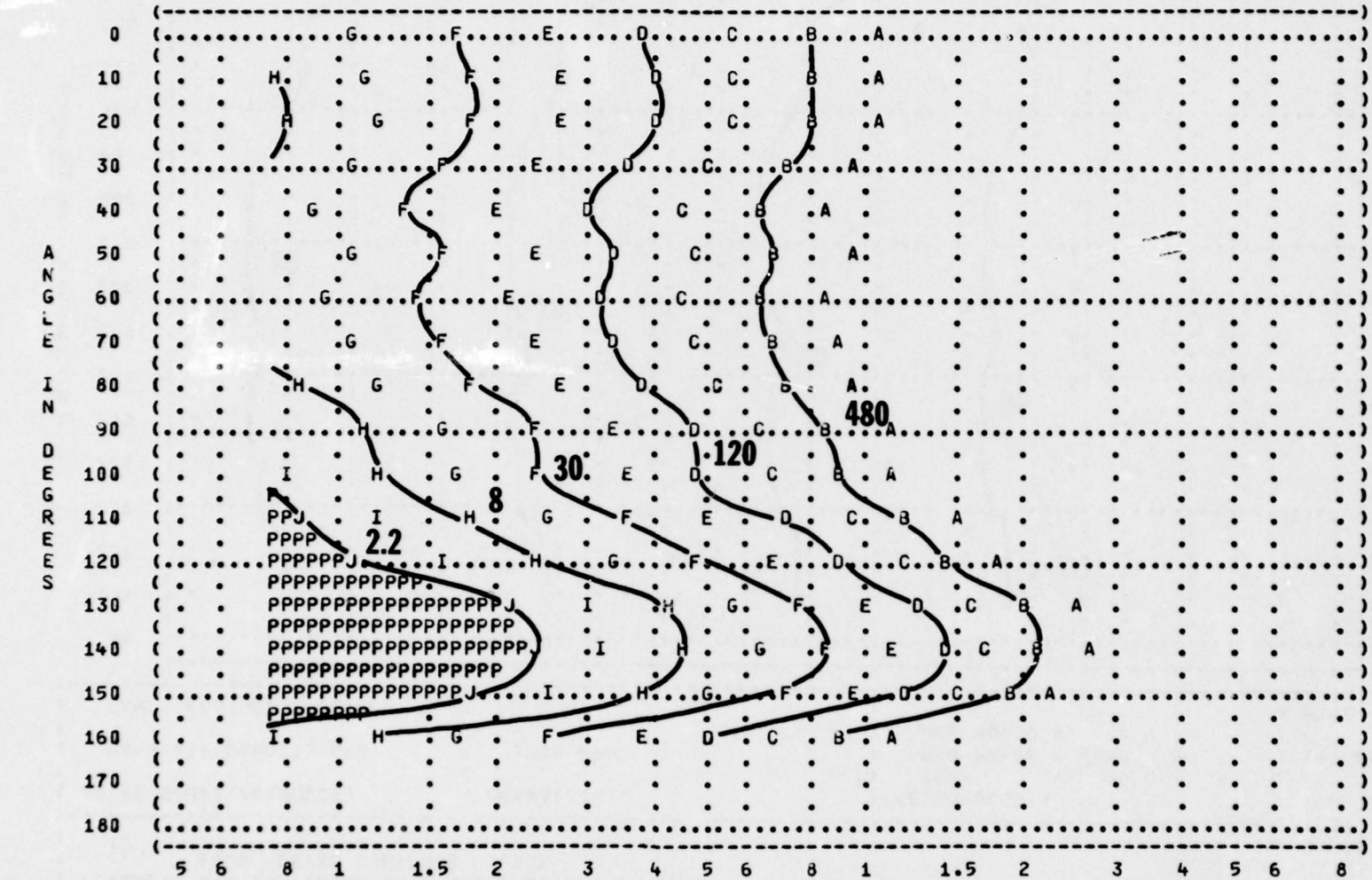
NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 7

POINT	MIN
A	960
B	480
C	240
D	120
E	60
F	30
G	15
H	8
I	4
J	2.2



P ADDITIONAL EAR PROTECTION REQUIRED.

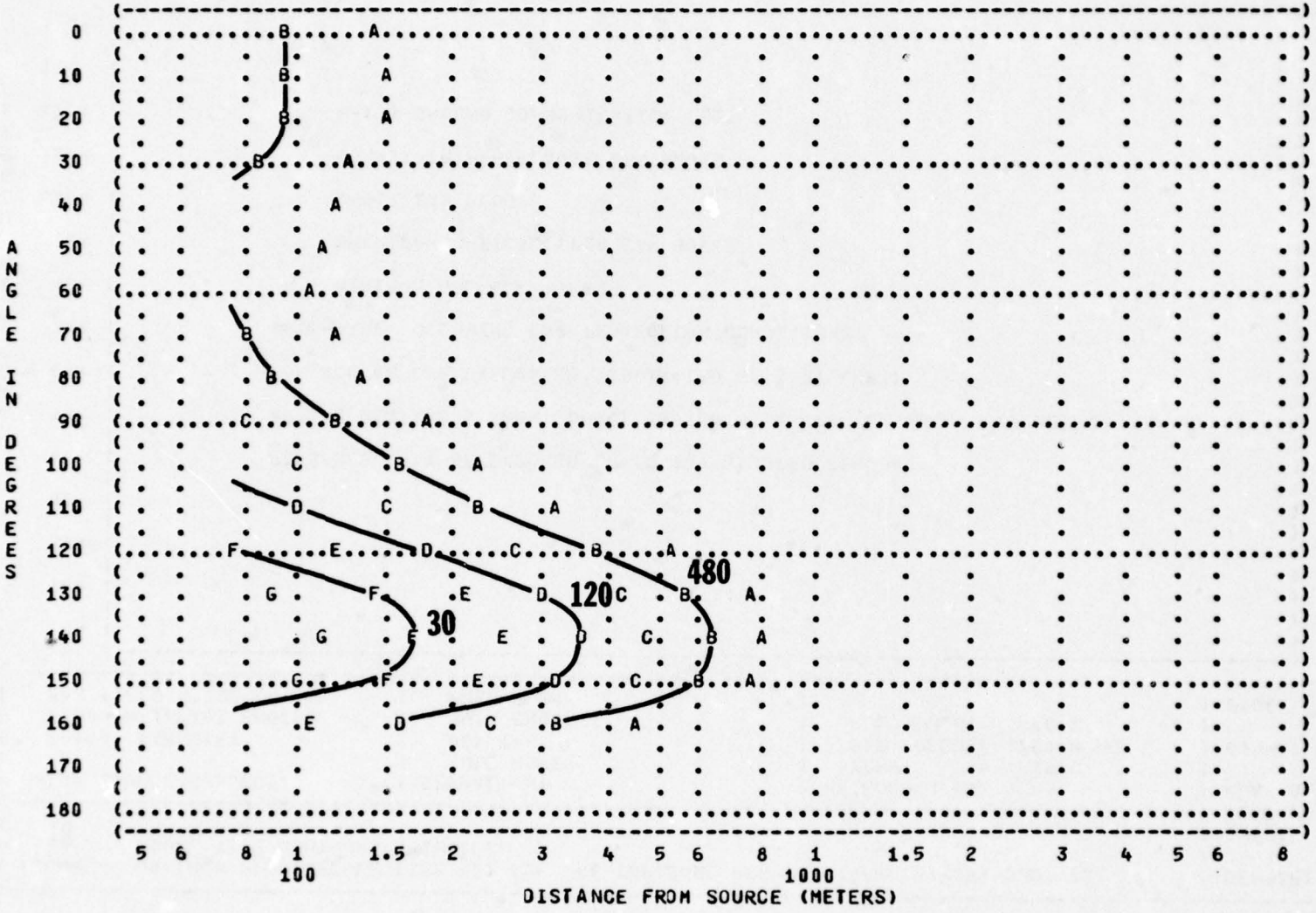
FIGURE 17: MAXIMUM PERMISSIBLE TIME (T) FOR ONE EXPOSURE PER DAY (AFR 161-35, JULY 73)
EQUAL TIME CONTOURS (MINUTES)
MINIMUM QPL EAR MUFFS

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 03
07 MAY 75
PAGE 8

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER
90% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	MIN
A	960
B	480
C	240
D	120
E	60
F	30
G	15

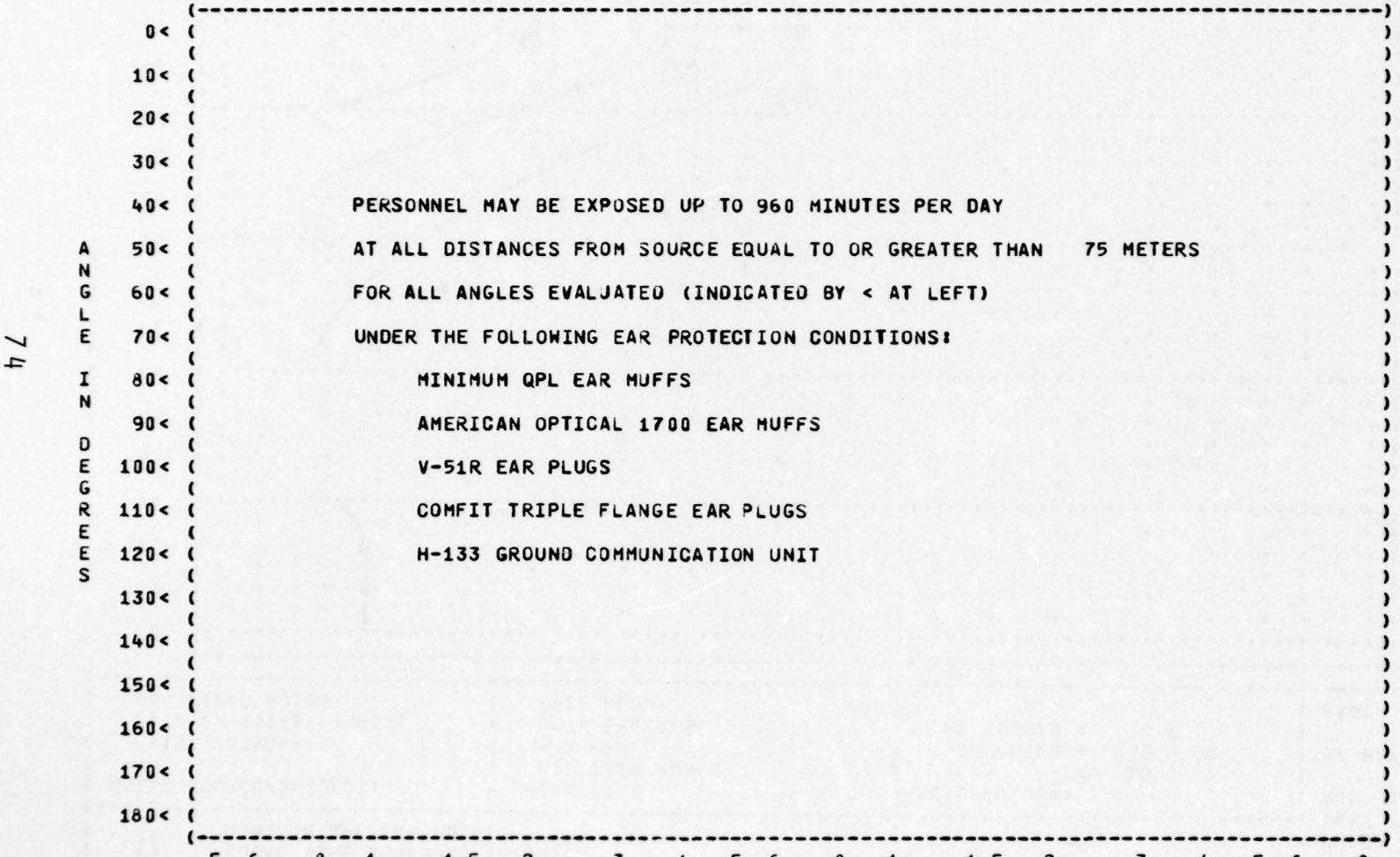
FIGURE: 18 MAXIMUM PERMISSIBLE TIME (T) FOR ONE EXPOSURE PER DAY (AFR 161-35, JULY 73)
EQUAL TIME CONTOURS (MINUTES)

IDENTIFICATION:
OMEGA 1.4
TEST 75-002-029
RUN 01
07 MAY 75
PAGE 8

NOISE SOURCE/SUBJECT:
F-15A AIRCRAFT
F100-PW-100(1) ENGINE
FAR FIELD NOISE

OPERATION:
IDLE POWER
60% RPM
BOTH ENGINES
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



ACCURACY OF DATA

The measured data reported in the handbook describe the noise environments produced by a particular source under the specific conditions existing at the time of individual tests. The accuracy of such measurements depended on the response, calibration, and stability of the complete acquisition and analysis system and knowledge of the type of sound field incident on the microphone (e.g., pressure field, free-field random incidence, free-field grazing incidence). **Measured SPL data** in the handbook are accurate within ± 1 dB for frequency bands below 6,300 Hz and ± 2 dB for the 6,300 to 10,000 Hz bands.

The measurement accuracy just cited specifies how accurately we measured the environments present at the time of test. It does not say how accurately these measured samples represent the environments produced for any particular type of source, operation or location. We discussed the sample times, spatial scanning techniques, and averaging times used to acquire and analyze these data. Generally, we measured only one sample of a particular type/model of source (e.g., only one F-15A aircraft or only one MD-3A generator set) and measured only one noise sample at each location for each test condition. Sometimes we repeated measurements to determine average, minimum or maximum levels. How representative are these noise samples?

The **in-flight and near-field handbook SPL data** are generally repeatable for like samples (i.e., same type source, same type operation, same measurement location, same type sampling method) within ± 3 dB for frequency bands below 6,300 Hz and ± 5 dB for the 6,300 to 10,000 Hz bands. The OASPL, OASLA, PSIL and other such levels summed, weighted, or averaged over frequency are typically repeatable within ± 3 dB for like samples.

We consider the handbook's **AGE far-field** measured at 5-10 meters from the units to show similar repeatability. But, **aircraft far-field data** measured at 35-125 meters or more from the source exhibit greater variability from test to test, principally because variances in meteorology directly affect the sound propagation. Repeatability of such measured data from like tests may or may not be good. The procedures used for the handbook to normalize the measured data to standard meteorological conditions remove much of this variability. We consider the repeatability of the handbook's **normalized, far-field aircraft data** for like samples to be about the same as for near-field data. The same repeatability applies for **PWL and DI** since their computation also corrects for meteorological effects on propagation. Although meteorology can affect source output, such changes are small compared with propagation effects and not considered significant for handbook purposes.

All **far-field noise contour sets** presented in the handbook represent *expected average levels* assuming meteorological conditions that, on the long-term, approximate the standard conditions of 15C temperature, 0.760 meter Hg barometric pressure, and 70% relative humidity. Why expected average levels? Because the extrapolation procedures used to derive these contours employ empirically-derived, analytical models that apply average values of atmospheric absorption and excess attenuation of sound based on large numbers of experimental measurements.

The data and procedures required to accurately predict far-field noise levels at large distances from a source for one test situation are neither developed nor practical. Such prediction would require detailed data on ground cover, terrain, micro-meteorology, etc., pertinent to that individual test situation and test day. Fortunately, in most cases, we are only seeking to define the average, typical noise environments associated with specific types of systems/operations.

If you go out on any one day and measure the far-field noise, say from an F-15 aircraft, you should not expect to get the same levels presented by the handbook contours. Variability of such individual samples about the expected mean value in the handbook will be high with typical standard deviations of 6-12 dB or more in band SPL. The average of repetitive measurements of like samples (i.e., same type source, same type operating conditions, same measurement locations) should, with increasing number of samples over weeks or months, tend to approximate the expected long-term average levels presented by the handbook using Volume 2[10] procedures if appropriate to obtain expected average levels for nonstandard meteorological conditions. Noise data for the standard conditions are sufficient for most airbase noise evaluations; refer to Volume 2 of the handbook.

REFERENCES

1. Farinacci, N. A., *USAF Bioenvironmental Noise Data Handbook, Volume 32: KC-135A In-Flight Crew Noise*, AMRL -TR-75-50(32), Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, 1975.

2. Powell, R. G., *USAF Bioenvironmental Noise Data Handbook, Volume 63: F-15A Near and Far-Field Noise*, AMRL-TR-75-50(63), Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH.

3. Farinacci, N. A., *USAF Bioenvironmental Noise Data Handbook, Volume 26: MA-3 Air Conditioner*, AMRL -TR-75-50(26), Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, 1975.

4. Speakman, J. D., Powell, R. G., and Cole, J. N., *Community Noise Exposure Resulting From Aircraft Operations: Acoustic Data on Military Aircraft*, AMRL-TR-73-110, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH, 1976.

5. Bishop, D. E., *Community Noise Exposure Resulting From Aircraft Operations: Application Guide for Predictive Procedure*, AMRL-TR-73-105, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH, 1974.

6. Galloway, W. J., *Community Noise Exposure Resulting From Aircraft Operations: Technical Review*, AMRL-TR-73-106, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH, 1974.

7. Bishop, D. E., *Community Noise Exposure Resulting From Aircraft Operations: Acquisition and Analysis of Aircraft Noise and Performance Data*, AMRL-TR-73-107, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH, 1975.

8. Reddingius, N. H., *Community Noise Exposure Resulting From Aircraft Operations: Computer Program Operator's Manual*, AMRL-TR-73-108, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH, 1974.

9. Horonjeff, R. D. Kandukuri, R. R., and Reddingius, N. H., *Community Noise Exposure Resulting From Aircraft Operations: Computer Program Description*, AMRL-TR-73-109, Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, 1974.

10. Cole, J. N., *USAF Bioenvironmental Noise Data Handbook, Volume 2: Procedure to Evaluate Effects of Non-Standard Meteorological Conditions on Far-Field Noise*, AMRL-TR-75-50(2), Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, 1975.

11. *Hazardous Noise Exposure.*, Air Force Regulation 161-35, Dept. of the Air Force, Washington, D. C., July 1973.

12. "Noise Standards: Aircraft Type Certification", Federal Aviation Regulations, Part 36, Dec 1969.

13. "Preferred Frequencies and Band Numbers for Acoustical Measurements", ANSI S1.6-1967, American National Standards Institute, 1967.

14. "Precision Sound Level Meters", IEC Publication 179, International Electrotechnical Commission, 1965.

15. Kryter, K. D., *The Effects of Noise on Man*, Academic Press, New York, 1970.

16. Webster, J. C., "Effects of Noise on Speech Intelligibility", *Proc Conference on Noise on a Public Health Hazard, Washington, D.C., June 13-14, 1968, ASHA Report 4*, American Speech and Hearing Association, Washington, D.C., 1969.

17. Peterson, A. P. G., E. E. Gross, Jr., *Handbook of Noise Measurements*, Seventh edition, General Radio Co., Cambridge, Mass., 1972.

18. Kryter, K. D., "Concepts of Perceived Noisiness, Their Implementation and Application", *J. Acoust Soc. Am. 43, 344-361*, 1968.

19. "Definitions and Procedures For Computing The Perceived Noise Level of Aircraft Noise", SAE Aerospace Recommended Practice 865A, Society of Automotive Engineers, Warrendale PA, 1969.

20. von Gierke, H. E., Harris, C. (ed), Chpt 33, "Aircraft Noise Sources," *Handbook of Noise Control*, McGraw Hill, New York, 1957.

21. Beranek, L. L., *Acoustics*, McGraw Hill, New York, 1954.

22. Stallkamp, R. A., "Segmental Surface Areas of a Sphere", UDRI-TM-69-07, Univ of Dayton Research Institute, Dayton, OH, 1969.

23. "Standard Values of Atmospheric Absorption As A Function of Temperature and Humidity", SAE Aerospace Recommended Practice 866A, Society of Automotive Engineers, Warrendale PA, 1975.

24. Franken, P. A., D. E. Bishop, *The Propagation of Sound From Airport Ground Operations*, NASA-CR-767, Langley Research Center, 1967.

25. Akima, H., "Interpolation and Smooth Curve Fitting Based on Local Procedures", *Communications of the Association for Computer Machinery, Vol. 15, No. 10*, Oct 1972.

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6570 AMRL/BB
WRIGHT-PATTERSON AFB OH 45433

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WRIGHT-PATTERSON AFB OH 45433

WRIGHT-PATTERSON AFB 1 CY
6570 AMRL/BBA
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APPENDIX B

TONE CORRECTION PROCEDURE

FAR Part 36*, Section B36.4 outlines a procedure to calculate a tone correction factor C which estimates the additional subjective noisiness of a particular sound spectrum due to tonal content. This factor is added to the perceived noise level (PNL) for that spectrum to derive a tone-corrected perceived noise level (PNLT). This procedure requires sound pressure levels (SPL) for 1/3 octave frequency bands, 80-10,000 Hz.

AMRL applied this procedure to calculate tone corrections applied to handbook data. We did not calculate C unless the spectrum contained at least 10 consecutive bands with SPL > 20 dB including the band with peak SPL. Normally, it contained all 22 bands, 80-10,000 Hz.

The procedure follows:

Step 1.

Starting with the measured sound pressure level in the 80 Hz one-third octave band (band number 3), calculate the changes in level (or "slopes") in the remainder of the bands as follows:

$$s(3) = \text{no value}$$
$$s(4) = SPL(4) - SPL(3)$$
$$\vdots$$
$$s(i) = SPL(i) - SPL(i-1)$$
$$\vdots$$
$$s(24) = SPL(24) - SPL(23)$$

Step 2.

Encircle the value of the slope s(i) where the absolute value of the change in slope is greater than five; that is, where

$$|\Delta s(i)| = |s(i) - s(i-1)| > 5$$

Step 3.

(a) If the encircled value of the slope s(i) is positive and algebraically greater than the slope s(i-1), encircle the level SPL(i).

(b) If the encircled value of the slope s(i) is zero or negative and the slope s(i-1) is positive, encircle the level SPL(i-1).

(c) For all other cases, no level is to be encircled.

Step 4.

Omit all SPL(i) encircled in Step 3 and compute new levels as follows:

(a) For nonencircled levels, let the new levels equal the original levels.

$$SPL'(i) = SPL(i)$$

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*"Noise Standards: Aircraft Type Certification", Federal Aviation Regulations, Part 36, Dec 1969.

(b) For encircled levels, let the new level equal the arithmetic average of the preceding and following levels.

$$SPL'(i) = \tfrac{1}{2}\,[SPL(i-1) + SPL(i+1)]$$

(c) If the level in the highest frequency band is encircled, let the new level equal

$$SPL'(24) = SPL\,(23) + s\,(24)$$

Step 5.

Recompute the new slopes including one for an imaginary 25th band as follows:

$$s'(3) = s'(4)$$
$$s'(4) = SPL'(4) - SPL'(3)$$
$$\vdots$$
$$s'(i) = SPL'(i) - SPL'(i-1)$$
$$\vdots$$
$$s'(24) = SPL'(24) - SPL'(23)$$
$$s'(25) = s'(24)$$

Step 6.

Compute the arithmetic average of the three adjacent slopes as follows:

$$\bar{s}(i) = 1/3[s'(i) + s'(i+1) + s'(i+2)]$$

Step 7.

Compute final adjusted levels by beginning with band number 3 and proceeding to band number 24 as follows:

$$SPL''(3) = SPL(3)$$
$$SPL''(4) = SPL''(3) + \bar{s}(3)$$
$$\vdots$$
$$SPL''(i) = SPL''(i-1) + \bar{s}(i-1)$$
$$\vdots$$
$$SPL''(24) = SPL''(23) + \bar{s}(23)$$

Step 8.

Calculate the difference between the original and adjusted levels as follows:

$$F(i) = SPL(i) - SPL''(i)$$

and note only values greater than zero.

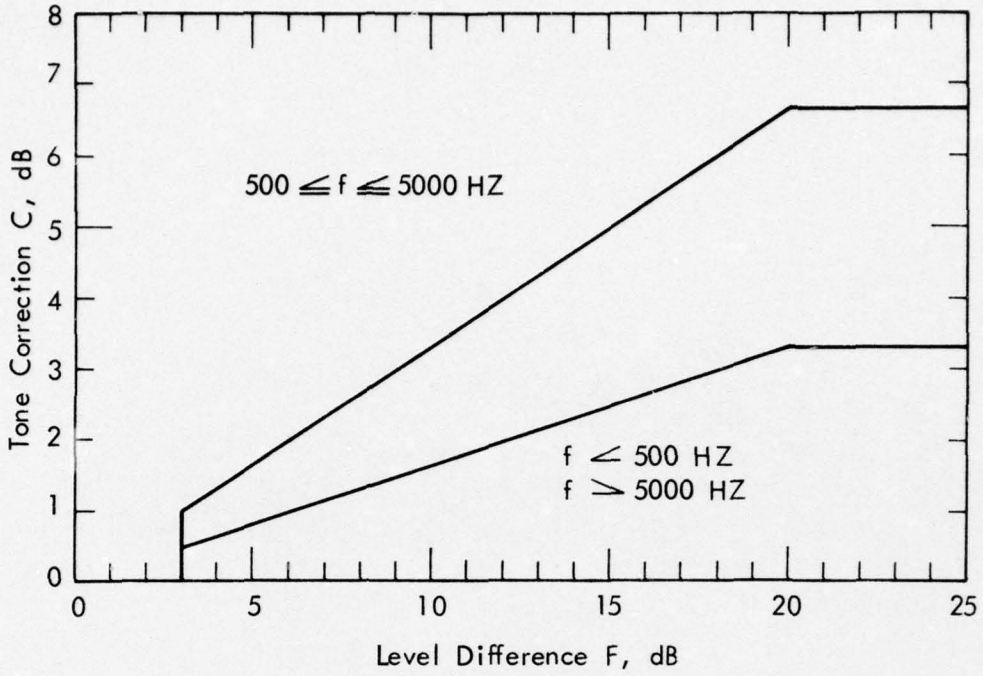
Step 9.

Tone correction levels C must be determined for any one-third octave band in accordance with Table B-1.

Step 10.

The maximum value of C determined in Step 9 defines the tone correction that must be added to the perceived noise level PNL to obtain the tone corrected perceived noise level PNLT.

TABLE B-1
TONE CORRECTION FACTORS



Frequency f, HZ	Level Difference F, dB	Tone Correction C, dB
50 ≤ f < 500	F < 3 3 ≤ F < 20 20 ≤ F	0 F/6 3 1/3
500 ≤ f ≤ 5000	F < 3 3 ≤ F < 20 20 ≤ F	0 F/3 6 2/3
5000 < f ≤ 10000	F < 3 3 ≤ F < 20 20 ≤ F	0 F/6 3 1/3

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